

American National Standard

ANSI X3.180-1990

*for Information Systems –
Magnetic Tape and Cartridge for
Information Interchange–
18-Track, Parallel,
1/2 inch (12.65 mm), 37 871 cpi
(1491 cpmm), Group-Coded –
Requirements for Recording*



American National Standards Institute

11 West 42nd Street
New York, New York
10036

American National Standard

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for Information Systems –

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Secretariat

Computer and Business Equipment Manufacturers Association

Approved January 22, 1990

American National Standards Institute, Inc

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Foreword (This Foreword is not part of American National Standard X3.180-1990.)

This standard presents format, recording, and cartridge requirements for 12.65-mm (1/2-inch), 18-track magnetic tape to be used for information interchange among processing systems, communication systems, and associated equipment utilizing the American National Standard Code for Information Interchange, ANSI X3.4-1986. This standard deals solely with recording on magnetic tape.

The X3B5 Subcommittee on Magnetic Tape, which developed this standard, consists of experienced and qualified specialists on manufacturing magnetic tape, and on recording digital information on magnetic tape. This standard is the first to utilize this cartridge form factor. The cartridge, magnetic tape, and recording format represent a significant advancement in reliability and volumetric efficiency for 12.65-mm (1/2-inch) magnetic tape. In the development of this standard, careful consideration was given to current practices, existing equipment and supplies, the broadest possible acceptance, and to providing a basis for future improvements in the use of the cartridge medium.

The standard contains specifications for the physical, magnetic, and performance properties of the magnetic media, the dimensions and characteristics of the cartridge, and the specifications for a recording format. The text of this standard differs from the corresponding ISO and ECMA standards ISO 9661 and ECMA-120; however, it is the intent of this standard to be technically the same.

This standard includes a number of new criteria that are the result of experiences obtained in high-density recording on magnetic tape. As additional experience is gained, improvement in test methods and the need for additional criteria should be expected. This is particularly relevant in the areas of debris generation and mechanical interaction between the magnetic tape and the recording head.

Requests for interpretation, suggestions for improvement or addenda, or defect reports are welcome. They should be sent to the X3 Secretariat, Computer and Business Equipment Manufacturers Association, 311 First Street NW, Suite 500, Washington, DC 20001-2178.

This standard was processed and approved for submittal to ANSI by Accredited Standards Committee on Information Processing Systems, X3. Committee approval of the standard does not necessarily imply that all members voted for its approval. At the time it approved this standard, the X3 Committee had the following members:

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1. Scope, Purpose, and Conformance

1.1 Scope. This standard provides the requirements for a tape cartridge to be used for information interchange among information-processing systems, communication systems, and associated equipment utilizing a standard code for information interchange as agreed upon by the interchange parties. Sections 4 through 8 of this standard provide the general requirements, definitions, physical and magnetic tape characteristics, and the tape-cartridge requirements. Sections 9 through 15 deal with the requirements for recording on magnetic tape. The use of a labeling standard such as American National Standard Tape Labels and File Structure for Information Interchange, ANSI X3.27-1987 or later editions, will support data interchange between data-processing systems.

CAUTION: The user's attention is called to the possibility that compliance with this standard may require the use of an invention covered by patent rights. By publication of this standard, no position is taken with respect to the validity of this claim or of any patent rights in connection therewith. However, the patent holder has filed a statement of willingness to grant a license under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license. Details may be obtained from the secretariat. No representation or warranty is made or implied that this is the only license that may be required to avoid infringement in the use of this standard.

1.2 Purpose. This standard defines the requirements and supporting test methods necessary to ensure information interchange at acceptable performance levels. It is distinct from a specification in that it delineates a minimum of restrictions consistent with compatibility in interchange transactions.

The performance levels contained in this standard represent the minimum acceptable levels of performance for interchange purposes. They, therefore, represent the performance levels that the interchange items should meet or surpass during their useful life and thus define end-of-life criteria for interchange purposes. The performance levels in this standard are not intended to be employed as substitutes for purchase specifications.

Wherever feasible, quantitative performance levels that shall be met or exceeded to comply with this standard are given. In all cases, including those in which quantitative limits for requirements falling within the scope of this standard are not stated but left to agreement between the interchange parties, standard test methods and measurement procedures shall be used to determine such limits.

The original dimensions and quantities for all numeric values in this standard are in the International System of Units (SI). Conversions of these units to U.S. Customary engineering units (similar to British Imperial units) and centimeter-gram-second electromagnetic units (cgs-emu) have been incorporated in accordance with the procedures described in American National Standard Metric Practice ANSI/IEEE 268-1982. Units of either of the two measurement systems may be referred to, but the two systems should not be intermixed or reconverted. Conversions of toleranced dimensions and quantities in this standard have been performed in accordance with Method A of ANSI/IEEE 268-1982 and International Standard Toleranced Dimensions – Conversions from Inches into Millimetres and Vice Versa, ISO 370-1975, to maintain the implied correspondence between the accuracy of the original data and the number of significant digits and rounding of the converted values. In the national standards of ISO member

bodies, additional rounding may be done to produce “preferred” values. These values should lie within or close to the original tolerances.

Except as indicated above, the interchange parties complying with the applicable standards should be able to achieve compatibility without the need for additional exchange of technical information.

1.3 Conformance. A magnetic tape cartridge conforms to this standard if it satisfies all mandatory requirements of this standard. The tape requirements shall be satisfied throughout the extent of the tape.

2. Referenced and Related Standards and Publications

2.1 Referenced American National Standards. This standard is intended to be used with the following American National Standards. When these referenced standards are superseded by a revision approved by the American National Standards Institute, the revision shall apply:

ANSI X3.4-1986, Information Systems – Coded Character Sets – 7-bit American National Standard Code for Information Interchange (7-bit ASCII)

ANSI X3.27-1987, Information Systems – File Structure and Labeling of Magnetic Tapes for Information Interchange

ANSI/IEEE 268-1982, Metric Practice

ANSI/UL 94-1985, Safety Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

2.2 Other Referenced Standards. This standard is also intended to be used with the following standards:

ISO 370: 1975, Toleranced Dimensions – Conversions from Inches into Millimetres and Vice Versa¹

ISO 9661: 1988, Information Processing – Data interchange on 12.7 mm (0.5 in) wide magnetic tape cartridge – 18 tracks, 1 491 data bytes per millimetre (13 871 data bytes per inch)¹

2.3 Referenced Publication. This standard is also intended to be used with the following publication:

ANSI X3-TR-1-82, American National Dictionary for Information Processing Systems²

2.4 Related Standards. The following standards are listed for information only and are not essential to complete the requirements of this standard.

ANSI Y14.5M-1988, Engineering Drawing and Related Documentation Practices, Dimensioning and Tolerancing

ISO 1302: 1978(E), Technical Drawings – Method of Indicating Surface Texture on Drawings¹

3. Definitions

The following definitions, listed in alphabetical order, and those given in the American National Dictionary for Information Processing Systems, ANSI X3-TR-1-82,² apply to this standard:

anhysteretic erase. A process of erasure utilizing alternating fields of decaying level.

average signal amplitude. The average peak-to-peak value of the signal output measured over a minimum of 25.4 mm (1.0 in), exclusive of dropouts.

azimuth. The angular deviation, in minutes of arc, of the mean flux transition line of a track from the line normal to the tape reference edge.

¹ Available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

² At the time of publication of this standard, ANSI X3-TR-1-82 had undergone revision and was redesignated as ANSI X3.172-1990.

back surface. The surface of the tape opposite the magnetic coating used to record data.

beginning-of-tape (BOT). Indicated by the start of the density-identification mark.

bit. A single digit in the binary number system.

bit-cell. A distance along the track between the initial flux transition of adjacent bits.

block. A group of contiguous recorded bytes considered and transported as a unit. Blocks are separated by an interblock gap.

byte. A contiguous set of eight data bits (9 encoded bits) that are acted on as a unit.

cartridge. A container holding a single supply reel of 12.65-mm (1/2-in) -wide magnetic tape with an attached leader block at the BOT end.

character. A unit of information, usually constituted as one or more bytes.

coincident dropouts. A coincident dropout is a simultaneous dropout condition on two or more tracks of a 9-track group. A coincident dropout is counted as a single event regardless of length. One group contains the odd-numbered tracks and the other group contains the even-numbered tracks.

control frame. A frame that has an identical data pattern in all 18 tracks.

cyclic redundancy check (CRC) character. A two-byte code derived from information contained in the data bytes, pad bytes, and residual byte.

data density. The number of single-byte characters stored per unit-length of tape. Usually expressed as characters per millimeter (cpmm) or characters per inch (cpi). Alternately, bytes per millimeter or bytes per inch may be used.

dropout. A dropout is a loss in read signal amplitude. A dropout exists when the base-to-peak read signal amplitude is 25 percent or less of half of the average signal amplitude for the preceding 25.4 mm (1.0 in) of tape, exclusive of dropouts.

end-of-tape (EOT). The last point on a tape for any recording (usually the final tape mark).

entity. A group of blocks treated as a logical unit.

erase record gap. An interval recorded at a location found to be defective at the time a tape is written. It is always preceded and succeeded by an interblock gap.

error-correcting code (ECC). A special sequence of bytes usable for error detection and correction.

flux-transition position. The point on the magnetic tape that exhibits the maximum free-space flux density normal to the tape surface.

flux-transition spacing. The distance on the magnetic tape between successive flux transitions.

frame. A logical section across all 18 tracks containing functionally related bytes (encoded 9-bit groups).

group-coded recording (GCR). A recording technique that collects 8-bit groups of data bits (one byte) and encodes them into 9-bit groups prior to recording them on magnetic tape.

interblock gap (IBG). A recorded section of tape separating blocks of information or other special marks.

magnetic tape. A tape that accepts and retains magnetic signals intended for input, output, and storage of data for information processing.

master standard reference tape. A tape selected as the standard for reference field, signal amplitude, resolution, and overwrite ratio.

NOTE: A master standard reference tape is being established at the National Institute of Standards and Technology (NIST) for this standard.

narrow-band signal-to-noise ratio. The average read signal power divided by the average integrated (side band) rms noise power and expressed in dB.

overwrite. The ratio of the average amplitude of the residual of the fundamental frequency of the tone pattern after being overwritten by the 972-ftpm (24-689 fti) signal to the average signal amplitude of the 972-ftpm (24-689 fti) signal. The average amplitude of the fundamental frequency of the tone pattern is the peak-to-peak amplitude of the sinusoidal signal with equal rms power.

physical recording density. The number of recorded flux transitions per unit length of track, e.g., flux transitions per millimeter (ftpm) or flux transitions per inch (fti).

postamble. A repeated 9-bit pattern at the end of each recorded block providing electronic synchronization when reading the tape in the reverse direction.

preamble. A repeated 9-bit pattern at the beginning of each recorded block providing electronic synchronization when reading the tape in the forward direction.

pre-record condition. The required remanent moment of the tape prior to recording data or testing.

recorded block. A group of contiguously recorded frames that extend from one interblock gap to the next interblock gap. The block includes preamble, beginning-of-data marks, prefix frames, data frames, resync marks, completion frames, residual frames, end-of-data marks, and postamble.

reference field. The typical field of the master standard reference tape.

resistance per square. The surface resistance of a square area, of any size, measured between electrodes placed on two opposite sides of the square. The unit of measurement is the ohm.

resolution. The ratio of the average signal amplitude at the physical recording density of 1458 ftpm (37 033 fti) to that at the physical recording density of 972 ftpm (24 689 fti).

resync mark. A control character identifying format resynchronization points in a track. It is intended that read-back circuits be capable of resynchronizing operations when such characters are sensed.

secondary standard reference tape. A tape, the performance of which is known and stated in relation to that of the master standard reference tape.

NOTE: Secondary standard reference tapes for this standard are being developed at the National Institute of Standards and Technology (NIST) and will be available from NIST, Office of Standard Reference Materials, Room B311, Chemistry Building, National Institute of Standards and Technology, Gaithersburg, MD 20899. It is intended that these be used for calibrating further reference tapes for use in routine calibration.

skew. The angular deviation of bits within a frame from a line perpendicular to the tape reference edge.

standard measurement current (I_m). A current whose value is 1.5 times the standard reference current ($I_m = 1.5 \cdot I_r$).

standard reference amplitude. The average signal amplitude from the master standard reference tape when it is recorded with the standard measurement current on the NIST measurement system at 972 ftpm (24 689 fti). Traceability to the standard reference amplitude is provided by the calibration factors supplied with each secondary standard reference tape.

standard reference current (I_r). The current that produces the reference field.

tape-reference edge. The reference edge of the tape is the bottom edge when viewing the recording side of the tape with the hub end (EOT) of the tape to the observer's right (see Figure 9).

tone pattern. The repeated 6-bit pattern 100000. When the tone pattern is written, all tracks in the given zone contain the tone pattern.

tone pattern fundamental frequency. The frequency that is one-sixth of the frequency of the 972 ftpm (24 689 fti) signal.

total character skew. The displacement between bits in the same vertical parity-check column, in a direction parallel to the tape reference edge.

track. A longitudinal area on the tape along which a series of magnetic signals can be recorded.

typical field. The minimum recording field which, when applied to a magnetic tape, will cause an average signal amplitude equal to 85 percent of the maximum average signal amplitude at 972-ft/mm (24-689 fpi) recording density.

zero crossing. The point at which the read signal passes through zero.

zone. A grouping of three tracks. The 18 tracks are divided into six distinct zones. Zones identify special marks and gaps.

4. Environment and Safety

Unless otherwise stated, the conditions specified below refer to the ambient conditions in the test or computer room and not to those within the tape equipment.

4.1 Testing Environment of Tape and Cartridge. Unless otherwise stated, tests and measurements made on the cartridge and tape to check requirements of this standard shall be carried out under the following conditions:

Temperature:	23°C ± 2°C (74°F ± 4°F)
Relative humidity:	40% to 60%
Conditioning before testing:	24 hours

4.2 Operating Environment of Cartridge. Cartridges used for data interchange shall be capable of operating under the following conditions:

Temperature:	
Ambient cartridge temperature:	16°C to 32°C (60°F to 90°F)
The average temperature of the air surrounding the tape shall not exceed:	40°C (104°F)

CAUTION: Localized tape temperatures in excess of 48°C (120°F) may cause tape damage.

Relative humidity:	20% to 80%
Maximum wet bulb temperature:	25°C (78°F)
Conditioning before operating:	If during storage or transportation a cartridge has been exposed to conditions outside the above values, it shall be conditioned for a period of at least 24 hours before use.

4.3 Storage Environment of Cartridge. Cartridges shall be stored under the following conditions:

Temperature:	5°C to 32°C (40°F to 90°F)
Relative humidity:	5% to 80%
Maximum wet bulb temperature:	26°C (80°F)

4.4 Transportation. Recommendations for transportation appear in Appendix A.

4.5 Safety

4.5.1 Safeness. The components of the tape and cartridge assembly shall not constitute any safety or health hazard when used in the intended manner, or through any foreseeable misuse in an information processing system.

4.5.2 Flammability. The materials used in the external cartridge covers shall have a flammability rating of at least 94V-2, as described in ANSI/UL 94-1985.

5. Mechanical and Electrical Requirements of Tape

5.1 Material. The tape shall consist of a base material (oriented polyethylene terephthalate film or its equivalent) coated on one side with a strong yet flexible layer of ferromagnetic material dispersed in a suitable binder. The back surface of the tape may be coated.

5.2 Length of Tape. The length of the tape shall not be less than 165 meters (541 feet).

5.3 Width. The width of the tape shall be $12.650 \text{ mm} \pm 0.025 \text{ mm}$ ($0.4980 \text{ inch} \pm 0.0010 \text{ inch}$). The width shall be measured across the tape from edge to edge when the tape is under a tension of less than 0.28 N (1.0 ozf).

5.4 Total Thickness. The total thickness of the tape at any point shall be between $25.9 \text{ }\mu\text{m}$ and $33.7 \text{ }\mu\text{m}$ ($1020 \text{ }\mu\text{in}$ and $1330 \text{ }\mu\text{in}$).

5.5 Base-Material Thickness. The thickness of the base material shall be $23.4 \text{ }\mu\text{m}$ ($921 \text{ }\mu\text{in}$) nominal.

5.6 Discontinuity. There shall be no discontinuities in the tape such as those produced by tape splicing or perforations.

5.7 Longitudinal Curvature. Longitudinal curvature is the departure from a straight line along the longitudinal dimension of the tape in the plane of the tape surface.

5.7.1 Requirement. The radius of curvature of the edge of the tape shall be greater than 33 meters (108 feet).

5.7.2 Procedure. Allow a 1-meter (39-inch) length of tape to unroll and measure its natural curvature on a flat, smooth surface. Measure the deviation from a 1-meter (39-inch) chord. The deviation shall not be greater than 3.8 mm (0.150 inch). This corresponds to the minimum radius of curvature of 33 meters (108 feet) when measured over an arc of circle.

5.8 Out-of-Plane Distortions. Out-of-plane distortions are local deformations that cause portions of the tape to deviate from the plane of the surface of the tape. Out-of-plane distortions are most readily observed when the tape is lying on a flat surface under no tension. All visual evidence of out-of-plane distortion shall be removed when the tape is subjected to a uniform tension of 0.6 N (2.16 ozf).

5.9 Cupping. Cupping is the departure across a tape (transverse to motion) from a flat surface.

5.9.1 Requirement. The departure across the width of tape from a flat surface shall be less than 0.3 mm (0.0118 inch).

5.9.2 Procedure. Cut a $1.0\text{-meter} \pm 0.1\text{-meter}$ ($39.4\text{-inch} \pm 3.9\text{-inch}$) sample of tape. Condition it for a minimum of three hours in the test environment by hanging it so that the coated surface is freely exposed to the test environment. From the center portion of the acclimated tape, cut a sample 25.4 mm (1 inch) in length. Stand the cut sample on its end in a cylinder 25.4 mm (1.0 inch) high and with an inside diameter of $13.0 \text{ mm} \pm 0.2 \text{ mm}$ ($0.5118 \text{ inch} \pm 0.0079 \text{ inch}$). With the cylinder standing on an optical comparator, measure the cupping by aligning the edges of the sample to the reticle and determining the distance from the aligned edges to the corresponding surface of the sample at its center.

5.10 Dynamic Frictional Characteristics. The force specified in 5.10.1 and 5.10.2 shall be the sum of the forces exerted by the 0.64-N (2.30-ozf) weight and the dynamic friction.

5.10.1 Frictional Drag between the Recording Surface and Back Surface. Frictional drag between the recording surface and the back surface is the resistance to motion between the recording surface and the back surface of the tape.

5.10.1.1 Requirement. The force required to move the recording surface relative to the back surface shall not be less than 1.0 N (3.60 ozf).

5.10.1.2 Procedure. Wrap a tape sample around a 25.4-mm (1.0-inch) diameter cylindrical mandrel with the back surface of the tape facing outward. Place a second sample of tape, with the recording surface facing inward, around the first sample for a total wrap angle of 90° . Attach one end of the outer test tape to a 0.64-N (2.30-ozf) weight. Attach the other end to a force gauge mounted on a motorized linear slide. Drive the slide at a speed of 1 mm/s (0.039 in/s). Connect the force gauge to a plotter to record the result. Particular attention should be given to keeping the samples clean.

5.10.2 Frictional Drag between the Recording Surface and Ferrite Surface. Frictional drag between the recording surface and ferrite is the force required to move the recording surface of the tape over a ferrite surface.

5.10.2.1 Requirement. The force required to move the tape at a point 1.34 meters (52.76 inches) from the leader block of the cartridge shall not be greater than 1.50 N (5.40 ozf).

The force required at a point 4.3 meters (169.3 inches) from the junction of the tape with the cartridge hub shall not exceed the first force by more than a factor of 4.

5.10.2.2 Procedure. Wind a sample of tape onto a 50-mm (2-inch) diameter spool hub to an outside diameter of 97 mm (4 inches). The winding tension shall be $2.2 \text{ N} \pm 0.2 \text{ N}$ ($7.91 \text{ ozf} \pm 0.72 \text{ ozf}$).

Repeat steps (1) and (2) five times before proceeding to step (3).

(1) Store at 50°C (122°F), 10% to 20% relative humidity, for 48 hours. The total storage time at 50°C (122°F) is 240 hours.

(2) Acclimatize at 23°C (73°F) for two hours and then unwind and rewind the tape on the spool hub at a tension of $2.2 \text{ N} \pm 0.2 \text{ N}$ (7.91 ozf $\pm$ 0.72 ozf).

(3) Acclimatize the tape for 48 hours at 31°C (87°F), 85% relative humidity. At this environment, measure the force required to pull the recording surface of the tape over 90° of a 25.4-mm (1-inch) diameter polished ferrite rod made of the material specified for the wear bar shown in Figure 1. The rod shall be polished to a surface finish of N2 (ISO 1302). See Figure 1.

(4) Pull the sample over the rod at a speed of 1 mm/s (0.04 in/s) while exerting a force of 0.64 N (2.30 ozf) on the other end.

(5) Take the measurements on tape samples at the outer diameter of the cartridge reel and near the hub.

5.11 Coating Adhesion. Coating Adhesion is the force required to peel any part of the coating from the tape base material.

5.11.1 Requirement. The force required to peel any part of the coating from the tape base material shall not be less than 1.5 N (5.4 ozf).

5.11.2 Procedure

(1) Take a sample of the tape approximately 380 mm (15 inches) long and scribe a line through the coating across the width of the tape 125 mm (5 inches) from one end.

(2) Using a double-sided pressure-sensitive tape, attach the full width of the sample to a smooth metal plate, with the recording surface facing the plate.

(3) Fold the sample over 180° adjacent to, and parallel with, the scribed line. Attach the metal plate and the free end of the sample to the jaws of a universal testing machine such that when the jaws are separated the tape is peeled. Set the jaw separation rate to 254 mm/min (10 in/min).

(4) Note the force at which any part of the coating first separates from the base material. If the sample peels away from the double-sided pressure-sensitive tape before the force exceeds the requirement, an alternative type of double-sided pressure tape shall be used.

(5) If the back surface of the tape is coated, repeat (1) to (4) for the back coating.

5.12 Flexural Rigidity. Flexural rigidity is the capability of the tape to resist bending in the longitudinal direction.

5.12.1 Requirement. The flexural rigidity of the tape in the longitudinal direction shall be between $0.06 \text{ N} \cdot \text{mm}^2$ and $0.16 \text{ N} \cdot \text{mm}^2$ ($0.21 \times 10^{-4} \text{ lbf} \cdot \text{in}^2$ and $0.56 \times 10^{-4} \text{ lbf} \cdot \text{in}^2$).

5.12.2 Procedure. Clamp a 180-mm (7.1-inch) tape sample in a universal testing machine, allowing a 100-mm (3.9-inch) separation between the machine jaws using a crosshead speed of 5 mm/min (0.2 in/min). Calculate the flexural rigidity using the slope of the curve between 2.2 N and 6.7 N (0.5 lbf and 1.5 lbf). The calculations are:

$$E = (\Delta F / WT) \times (1 / (\Delta L / L))$$

$$I = WT^3 / 12$$

$$\text{Flexural rigidity} = EI = \Delta F T^2 / (12 \Delta L / L)$$

where

ΔF = Change in force in N (lbf)

T = Measured thickness in mm (inches)

W = Measured width in mm (inches)

$\Delta L / L$ = Change in sample length between the jaws divided by the original length between the jaws

5.13 Electrical Resistance of the Coated Surface. Electrical resistance is the resistance of the coated surface, measured in ohms per square.

5.13.1 Requirement. The electrical resistance of the recording surface shall not exceed 5×10^8 ohms per square for non-backcoated tape, and 5×10^9 ohms per square for backcoated tape, but shall be greater than 10^5 ohms per square. The electrical resistance of any backcoat shall be less than 1×10^6 ohms per square.

5.13.2 Procedure. After 24 hours exposure to the test environment, two layers of the sample tape shall be placed back to back between the strip electrodes as shown in Figures 2 and 3 such that the coated surfaces under test are in contact with all of the electrodes. In mounting the sample for measurement, it is important that no conduction paths exist between the electrodes, except those through the sample. To ensure that the length of tape held between each

strip electrode is the same, the sample shall be placed under $2.23 \text{ N} \pm 0.56 \text{ N}$ ($8.0 \text{ ozf} \pm 2.0 \text{ ozf}$) tension as it is being clamped.

NOTE: Neither the sample nor the insulating surfaces shall be handled with bare fingers. (The use of clean, lint-free gloves is recommended.)

Measurements shall be made between each pair of adjacent electrodes, producing a total of five readings per sample. The resistance of the coating shall be determined by means of a guarded circuit, as shown in Figure 3, using $500 \text{ volts} \pm 10 \text{ volts}$ potential.

Average the five resistance readings.

5.14 Pre-Record Condition. The tape shall have been anhysteretically erased to ensure that the remanent magnetic moment of the recording surface does not exceed 20 percent of the maximum remanent magnetic moment and that no low-density transitions are present on the tape.

NOTE: See Appendix C for the explanation of the requirement and for a suggested method of measurement.

5.15 Inhibitor Tape. An inhibitor tape is any tape that degrades the performance of the tape drive or other tapes.

Certain tape characteristics can contribute to poor tape drive performance. Tapes that exhibit these characteristics may not give satisfactory performance, can result in excessive errors, and can interfere with the subsequent performances of other tapes.

5.15.1 Inhibitor Characteristics. These characteristics include:

- High abrasivity
- High friction to tape path components
- Poor edge conditions
- Excessive tape wear residual products
- Electro-static charge build-up on the tape or tape path components
- Interlayer slippage
- Transfer of oxide coating to the back of the next tape layer
- Separation of tape constituents causing deposits that may lead to tape sticking or poor performance of other tapes.

These parameters are important for interchange; however, except for abrasivity, definitive tests are not available at this time.

5.15.2 Requirement. The tape shall not be an inhibitor tape.

5.16 Abrasivity. Tape abrasivity is the tendency of the tape to wear the tape transport.

5.16.1 Requirement. Wear of the tape transport is simulated using a ferrite wear bar. The length of the wear pattern on a wear bar shall not exceed 0.056 mm (0.0022 inch).

5.16.2 Procedure. Install a clean ferrite wear bar made as shown in Figure 1 on a holding fixture similar to that shown in Figure 4. The test edge facing upward shall be unworn and free of chips or voids greater than $1 \mu\text{m}$ ($39 \mu\text{in}$). The radius of the test edge shall not be greater than $13 \mu\text{m}$ ($512 \mu\text{in}$).

(1) Install the test fixture on a tape transport so that the wrap angle of the tape over the bar is 8 degrees on each side, for 16 degrees of total wrap.

(2) Set the tape tension at the bar at 1.4 N (5.04 ozf).

(3) With a tape speed of 1 m/s (39 in/s), make one pass of the tape over the wear bar. The length of tape passing over the wear bar should be $520 \text{ meters} \pm 2.5 \text{ meters}$ ($1706 \text{ feet} \pm 8.2 \text{ feet}$). This length may be segmented into the appropriate number of cartridges.

(4) Remove the holding fixture from the transport and measure the length of the flat worn on the wear bar. This measurement is most easily made using a microscope of known magnification, a camera, and a reference reticle. Magnification of 300X or higher is recommended. Measurements should be taken at the $1/4$, $1/2$, and $3/4$ points of the 12.65-mm (0.498-inch) width of the wear pattern. The three readings are averaged and the average length is used. Figure 5 shows a typical wear pattern and the points of measurements.

6. Magnetic-Recording Performance of Tape

The magnetic-recording performance is defined by the testing requirements given in the following paragraphs. When performing the tests, the output or resultant signal shall be measured on the same relative pass for both the

reference tape and the tape under test (read-while-write, or on equipment without read-while-write capability, on the first forward-read-pass) on the same equipment.

The following conditions shall apply to all magnetic recording testing requirements, unless otherwise noted:

- Tape condition: pre-record condition
- Tape speed: ≤ 2.5 m/s (98.47 in/s)
- Read-track: within the written track
- Azimuth alignment: $\leq 6^\circ$ between the mean write transitions and the read gap
- Write-gap length: $1.4 \mu\text{m} \pm 0.2 \mu\text{m}$ ($55.1 \mu\text{in} \pm 7.9 \mu\text{in}$)
- Write head saturation density: $0.34 \text{ T} \pm 0.03 \text{ T}$ ($3400 \text{ gauss} \pm 300 \text{ gauss}$)
- Tape tension: $2.2 \text{ N} \pm 0.2 \text{ N}$ ($7.91 \text{ ozf} \pm 0.72 \text{ ozf}$)
- Recording current: standard measurement current (I_m)

6.1 Typical Field. The typical field of the tape shall be between 90 percent and 110 percent of the reference field. Traceability to the reference field is provided by the calibration factors supplied with each secondary standard reference tape.

6.2 Signal Amplitude. The average signal amplitude at the physical recording density of 972 ftpmm (24 689 ftpi) shall be between 70 percent and 140 percent of the standard reference amplitude. Traceability to the standard reference amplitude is provided by the calibration factors supplied with each secondary standard reference tape.

6.3 Resolution. The resolution of the tape shall be between 80 percent and 120 percent of that for the master standard reference tape. Traceability to the resolution of the master standard reference tape is provided by the calibration factors supplied with each secondary standard reference tape.

6.4 Overwrite

6.4.1 Requirement. The overwrite ratio for the tape shall be less than 120 percent of the same ratio for the master standard reference tape. Traceability to the overwrite ratio of the master standard reference tape is provided by the calibration factors supplied with each secondary standard reference tape.

6.4.2 Procedure. A tone pattern is recorded at the standard measurement current (I_m). A 972-ftpmm (24 689-ftp) signal is then recorded over the tone pattern at the standard measurement current (I_m). Measure the average signal amplitude of the residual of the tone pattern fundamental and the average signal amplitude of the 972-ftpmm (24 689-ftp) signal. Both amplitude measurements should be made using suitable filters.

6.5 Narrow-Band Signal-to-Noise Ratio (NB-SNR). The narrow-band signal-to-noise ratio is the average read-signal power divided by the average integrated (side band) rms noise power, and is expressed in dB.

6.5.1 Requirement. The NB-SNR shall be equal to or greater than 30 dB when normalized to a track width of $410 \mu\text{m}$ (0.016 14 μin). The normalization factor is:

$$\text{dB}(410) = \text{dB}(W) + 10 \cdot \log 410/W$$

where:

W is the track width used when measuring $\text{dB}(W)$.

6.5.2 Procedure. The NB-SNR shall be measured using a spectrum analyzer. The spectrum analyzer resolution bandwidth (RBW) shall be 1 kHz and the video bandwidth (VBW) shall be 10 Hz. The tape speed shall be 762 mm/s (30 in/s).

(1) Measure the read-signal amplitude of the 972-ftpmm (24 689-ftp) signal using a spectrum analyzer, taking a minimum of 150 samples over a length of tape of 46 meters (151 feet) minimum.

(2) On the next pass (read only), measure the rms noise power over the same section of tape and integrate the rms noise power (normalizing for the actual resolution bandwidth) over the range from 332 kHz to 366 kHz.

For other tape speeds the frequencies must be linearly scaled.

7. Quality of Tape

The quality of the tape (including the effects of exposure to storage and shipping environments) is defined by the testing requirements given in the following paragraphs. The following conditions shall apply to all quality testing requirements:

- Environment: operating environment
- Tape condition: pre-record condition

- Tape speed: 2 m/s (78.7 in/s)
- Read-track width: 410 μm (0.01614 inch).
- Physical recording density: 972 fpm (24 689 fpi)
- Write-gap length: 1.4 $\mu\text{m} \pm 0.2 \mu\text{m}$ (55.1 $\mu\text{in} \pm 7.9 \mu\text{in}$)
- Azimuth alignment: $\leq 6^\circ$ between the mean write transitions and the read gap
- Write head saturation density: 0.34 T $\pm$ 0.03 T (3400 gauss $\pm$ 300 gauss)
- Recording current: standard measurement current (I_m)
- Format: 18-track
- Tape tension: 2.2 N $\pm$ 0.2 N (7.91 ozf $\pm$ 0.72 ozf)

7.1 Dropout. A dropout is a loss of read signal amplitude. A dropout exists when the base-to-peak read signal amplitude is 25 percent or less of half of the average signal amplitude for the preceding 25.4 mm (1.0 inch) of tape, exclusive of dropouts. When a dropout is detected, a second dropout should not be counted until 64 consecutive dropout-free flux transitions are read. If a dropout persists for a distance of 1.0 mm (0.039 inch), another dropout is counted.

The average dropout rate shall be less than one dropout for each 8×10^6 flux changes recorded. The average dropout rate is the total number of flux transitions recorded on tape divided by the number of dropouts counted.

7.2 Coincident Dropout. A coincident dropout is a simultaneous dropout condition on two or more tracks of a 9-track group. A coincident dropout is counted as a single event regardless of length. There are two 9-track groups in the 18-track format. One group consists of the odd-numbered tracks and the other group consists of the even-numbered tracks.

A coincident dropout occurring in both groups at the same time is counted as a single event. The length of a combined coincident dropout event is measured from the start of the earliest event of either group to the end of the latest event of either group. This is equivalent to the logical "OR" of the coincident-dropout-event indicators for the two groups.

No 165-meter length of tape shall have more than 12 coincident dropouts. A coincident dropout shall not be longer than 50 mm (2 inches).

7.3 Durability of Tape. The recommended procedures for evaluating tape durability are described in Appendix B.

8. Mechanical Specifications of the Tape Cartridge

The tape cartridge shall consist of the following elements:

- case
- write-protect mechanism
- reel for the magnetic tape
- locking mechanism for the reel
- magnetic tape wound on the hub of the reel
- leader block
- latching mechanism for the leader block

Dimensional characteristics are specified for those parameters deemed mandatory for interchange and compatible use of the cartridge (see Figure 6 and Table 1). All dimensions have a tolerance of $\pm 0.25 \text{ mm}$ ($\pm 0.010 \text{ inch}$) unless otherwise noted. Where there is freedom of design, only the functional characteristics of the elements described are indicated.

Where they are purely descriptive, the dimensions refer to three reference surfaces A, B, and C, which form a geometrical trihedral (see Figure 7). Where the dimensions are related to the position of the cartridge in the drive, they may be referred to another surface of the cartridge.

8.1 Label Areas of Cartridge Case. Label areas on the top and side of the cartridge case are specified by I_9 , I_{10} , I_{11} , I_{13} , and I_{14} in Figure 6(a). Both label areas shall be recessed 0.50 mm $\pm$ 0.25 mm (0.020 inch $\pm$ 0.010 inch).

8.2 Locating Areas of Cartridge Case. The bottom side of the cartridge case shall have three circular locating areas: a_1 , a_2 , and a_3 (see Figure 6(b)), which shall lie in the same horizontal plane within 0.25 mm (0.010 inch). Dimensions to the bottom-surface, C, of the cartridge case shall be made to the plane defined by these areas.

8.3 Flexibility of Cartridge Case. The cartridge case top/bottom flexibility is the amount of deflection observed when the cartridge is loaded with a point force.

8.3.1 Requirement. The cartridge top shall deflect by an amount such that:

$$0.0256 \cdot l \text{ N} \leq d \leq 0.38 + 0.054 \cdot l \text{ N}$$

$$(0.0045 \cdot l \text{ lbf} \leq d \leq 0.015 + 0.0095 \cdot l \text{ lbf})$$

and the cartridge bottom shall deflect by an amount such that:

$$0.0228 \cdot l \text{ N} \leq d \leq 0.38 + 0.040 \cdot l \text{ N}$$

$$(0.0040 \cdot l \text{ lbf} \leq d \leq 0.015 + 0.0070 \cdot l \text{ lbf})$$

where:

d is the measured deflection in mm (inch)

l is the applied load

The applied load shall be between 4.5 N (1.0 lbf) and 54.0 N (12.1 lbf).

8.3.2 Procedure. The cartridge case flexibility shall be measured in a universal testing machine operating in the compression mode. A suitable load cell shall be used for the test. A single point load with a radius of $10 \text{ mm} \pm 1 \text{ mm}$ ($0.394 \text{ inch} \pm 0.039 \text{ inch}$) shall be applied on the bottom and subsequently on the top of the cartridge at the points indicated by the intersection of dimensions $l65$ and $l66$ (see Figure 6(a)).

8.4 File-Protect Mechanism. The write-protect mechanism shall have a flat surface identified by a visual mark, e.g., a white spot, when in the position in which writing is inhibited. In the write-inhibit position the surface of the write-protect mechanism shall be behind the front surface of the cartridge case a minimum distance of 2.55 mm (0.1004 inch).

In the write-enable position the write-protect mechanism shall be within 0.25 mm (0.010 inch) of the front side of the case.

The file-protect assembly shall activate when a force between 2 N and 9 N (0.45 lbf and 2.02 lbf) is applied at a tangent to the surface of the cartridge.

8.5 Tape-Reel Hub. The requirements of the tape-reel hub are:

- Straightness: 0.04 mm (0.00157 inch)
- Perpendicularity to datum P: 0.07 mm (0.00276 inch)
- Maximum conical taper: 0.05 mm : 13.05 mm
(0.00197 inch : 0.51378 inch)
- Rate-of-change
(across the width): 0.025 mm per mm
(0.0010 inch per 0.0394 inch)
- Full indicator movement
(FIM) to datum P: 0.2 mm (0.0079 inch)

NOTE: Datum P is a plane defined by the pitch line of the hub teeth at the 41-mm (1.614-in) diameter (Figures 6(c) and (d)).

8.6 Metallic Insert. The reel shall have a metallic insert made of 410 or 416 stainless steel. It shall withstand a pull-out force of 300 N (67.4 lbf) minimum. Its central opening (diameter $d3$) shall be concentric with the axis of rotation of the reel within 0.15 mm (0.006 inch). The surface of the metallic insert shall be parallel to datum P to within 0.15 mm (0.006 inch).

8.7 Brake Mechanism

8.7.1 Brake-Button Material. The brake-button material shall be nylon 6/6 with $2\% \pm 1\%$ molybdenum disulfide or equivalent.

8.7.2 In-Hand Position. The brake mechanism shall inhibit the rotation of the reel when the cartridge is in the in-hand position. The brake mechanism angular resolution shall not be more than 6 degrees in the in-hand position. In the locked position the reel shall not rotate more than 10 degrees when a torque of $0.32 \text{ N} \cdot \text{m}$ ($2.83 \text{ lbf} \cdot \text{in}$) is applied in the direction that will cause the tape to unwind.

8.7.3 In-Machine Position. The brake mechanism shall be disengaged when the cartridge is in the in-machine position with the tip of the brake button displaced $8.1 \text{ mm} \pm 0.2 \text{ mm}$ ($0.3189 \text{ inch} \pm 0.0079 \text{ inch}$) (see Figures 6(e) and (f) $l46$) from the bottom of the cartridge case. The force required to move the brake button into this position shall not exceed 12.25 N (2.75 lbf).

8.8 Winding of Tape. The tape shall be wound around the tape-reel hub such that it forms a counterclockwise spiral when the cartridge is viewed from the top. The recording surface of the tape shall be toward the hub. Particular attention should be given to the design of the reel and flange assembly to minimize tape offset.

8.9 Winding Tension. The tape shall be wound with a tension of $2.2 \text{ N} \pm 0.3 \text{ N}$ ($7.9 \text{ ozf} \pm 1.1 \text{ ozf}$).

8.10 Circumference of Tape Reel. The tape shall be wound to a circumference of between 280 mm and 307 mm (11.02 inches and 12.09 inches).

8.11 Moment of Inertia of Tape Reel. The moment of inertia of the tape reel is the ratio of the torque applied to it (complete with tape, hub, and flanges) when it is free to rotate about a given axis to the angular acceleration thus produced about that axis.

8.11.1 Requirement. The moment of inertia of the reel and tape shall be:

Between $145 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ and $180 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ ($0.495 \text{ lb} \cdot \text{in}^2$ and $0.615 \text{ lb} \cdot \text{in}^2$) when the circumference is between 280 mm and 289 mm (11.02 inches and 11.38 inches).

Between $160 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ and $195 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ ($0.547 \text{ lb} \cdot \text{in}^2$ and $0.666 \text{ lb} \cdot \text{in}^2$) when the circumference is between 289 mm and 298 mm (11.38 inches and 11.73 inches).

Between $180 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ and $216 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ ($0.615 \text{ lb} \cdot \text{in}^2$ and $0.738 \text{ lb} \cdot \text{in}^2$) when the circumference is between 298 mm and 307 mm (11.73 inches and 12.09 inches).

The empty reel moment of inertia shall be $33.00 \times 10^{-6} \text{ kg} \cdot \text{m}^2 \pm 3.63 \times 10^{-6} \text{ kg} \cdot \text{m}^2$ ($0.113 \text{ lb} \cdot \text{in}^2 \pm 0.012 \text{ lb} \cdot \text{in}^2$).

8.11.2 Procedure. Torsionally oscillate the reel assembly on an inertia dynamics unit. The oscillation period should be measured electronically with a universal counter. The oscillation time should then be converted to its rotational inertia value.

8.12 Leader Block Tape Attachment. There shall be a cylindrical insert for attaching the tape to the leader block. It shall cover the full width of the tape and not protrude beyond the surfaces of the leader block.

In zone Z the bottom edge of the tape (see Figure 6(g)) shall be parallel to the edge of the leader block within 0.12 mm (0.005 inch).

When attached to the leader block the end of the tape shall not protrude above the surface of the leader block by more than $159 = 2.5 \text{ mm}$ (0.1 inch).

The leader block shall remain attached to the tape when a force of 10 N (2.25 lbf) is applied to the leader block at an angle of $38^\circ \pm 2^\circ$ (see Figure 6(g) angle $\mu 4$).

8.13 Leader Block Pickup Position. The leader block pickup position when the leader block is latched in the cartridge is given by basic dimensions $l17$ and $l18$ in Figure 6(a). The leader block pickup point is the center of the hole defined by $l51$ and $l54$ (see Figure 6(h)). The pickup point must fall within a 0.5-mm (0.0197-inch) radius of the intersection of $l17$ and $l18$.

8.14 Leader Block Insertion Force. The leader block insertion force is the amount of force required to push the leader block into its latched position in the cartridge.

8.14.1 Requirement. The insertion force shall not exceed 12 N (2.7 lbf) through the insertion angle range of 45° to 51° (see Figure 6(g) angle $\mu 5$).

8.14.2 Procedure

(1) Clamp the cartridge in a fixture such that the leader block can be inserted by a universal testing machine at angles from 45° to 51° to the cartridge.

(2) Seat the $r13$ end of the leader block (see Figure 6(h)) in the cartridge opening and latch the $r14$ end of the leader block using a jaw speed of 10 mm/min (0.4 in/min). The leader block should be inserted with a pin that fits into diameters $d7$ and $d8$. The leader block should pivot freely on the pin.

8.15 Leader Block Pull-Out Force and Work. The leader block pull-out force is the amount of force required to unlatch the leader block from the cartridge. Pull-out work is the product of the maximum pull-out force and the

displacement distance. Displacement distance is the distance from the point that the pull-out force first exceeds 0.5 N (0.112 lbf) to the point that the maximum pull-out force starts to decrease.

8.15.1 Requirement. The leader block pull-out force shall be between 2.0 N (0.45 lbf) and 7.5 N (1.69 lbf). The leader block pull-out work shall not be greater than 13 N • mm (0.115 lbf • in).

8.15.2 Procedure

(1) Clamp the cartridge in a fixture such that the leader block can be extracted by a universal testing machine at angles from 45° to 51° to the cartridge (see Figure 6(g) dimension $\mu 5$).

(2) Set the jaw separation speed at 10 mm/min (0.4 in/min) and pull the leader block from the cartridge using a pin that fits into diameters d7 and d8. The leader block should pivot freely on the pin.

(3) Determine the maximum force and the product of the maximum force and the displacement distance.

9. Recording

The method of recording shall be double-density NRZI (non-return to ZERO, change on ONES).

NOTE: A ONE is represented by a transition at the beginning of a bit-cell and no transition at the center of the bit-cell. A ZERO is represented by a transition at the beginning of the bit-cell followed by a transition at the center of the bit-cell.

9.1 Physical Recording Density. The physical recording density shall be:

For all ZEROS: 1944 ftpmm (49 378 ftpi)

For all ONES: 972 ftpmm (24 689 ftpi)

9.2 Bit-Cell Length. The resulting nominal bit-cell length is 1.029 μm (40.504 μin).

9.3 Average Bit-Cell Length. The average bit-cell length is the sum of distances over n bit cells divided by n .

9.4 Long-Term Average Bit-Cell Length. The long-term average bit-cell length shall be the average bit-cell length taken over a minimum of 972 000 bit-cells. It shall be within ± 4 percent of the nominal bit-cell length.

9.5 Short-Term Average Bit-Cell Length. The short-term average bit-cell length (STA) shall be the average taken over 16 bit-cells. It shall be within ± 7 percent of the nominal bit-cell length.

9.6 Rate of Change. The rate of change of any two adjacent short-term average bit-cell length measurements shall not exceed 1.6 percent (see Figure 8).

9.7 Bit Shift. The maximum displacement of any ONES zero crossing, exclusive of dropouts, shall not deviate by more than 28 percent from the expected nominal position as defined by the average bit-cell length. See Appendix D for test procedure.

9.8 Total Character Skew. No data bit belonging to the same written transversal column shall be displaced by more than 19 bit-cell lengths when measured in a direction parallel to the tape-reference edge.

9.9 Read Signal Amplitude. The average signal amplitude of an interchanged cartridge averaged over 4000 flux transitions at 972 ftpmm (24 689 ftpi) shall be between 60 percent and 150 percent of the standard reference amplitude. Averaging for the interchange cartridge may be segmented into blocks. Traceability to the standard reference amplitude is provided by the calibration factors supplied with each secondary standard reference tape.

9.10 Coincident Dropouts. No coincident dropouts are permitted in a recorded block.

10. Format of Track

10.1 Number of Tracks. There shall be 18 tracks.

10.2 Reference Edge of Tape. The reference edge of the tape is the bottom edge when viewing the recording side of the tape with the hub end (EOT) of the tape to the observer's right (see Figure 9).

10.3 Positions of Track. The distance from the centerline of the tracks to the tape reference edge shall be:

Track 1:	11.68 mm (0.4598 in)
Track 2:	11.05 mm (0.4350 in)
Track 3:	10.42 mm (0.4102 in)
Track 4:	9.79 mm (0.3854 in)
Track 5:	9.16 mm (0.3606 in)
Track 6:	8.53 mm (0.3358 in)
Track 7:	7.90 mm (0.3110 in)
Track 8:	7.27 mm (0.2862 in)
Track 9:	6.64 mm (0.2614 in)
Track 10:	6.01 mm (0.2366 in)
Track 11:	5.38 mm (0.2118 in)
Track 12:	4.75 mm (0.1870 in)
Track 13:	4.12 mm (0.1622 in)
Track 14:	3.49 mm (0.1374 in)
Track 15:	2.86 mm (0.1126 in)
Track 16:	2.23 mm (0.0878 in)
Track 17:	1.60 mm (0.0630 in)
Track 18:	0.97 mm (0.0382 in)

The tolerance shall be ± 0.040 mm (± 0.0016 inch) for all tracks.

10.4 Width of Track. The width of the recorded track shall be 0.540 mm ± 0.017 mm (0.021 26 inch ± 0.000 67 inch).

10.5 Azimuth. The azimuth shall be less than 3 minutes of arc.

NOTE: At the time of tape recording, the azimuth should be less than 1 minute of arc. The remaining 2 minutes of arc are the allowance for tape distortion caused by environmental conditions and aging.

10.6 Identification of Track. Tracks are numbered consecutively, ending at the tape reference edge with track 18, and assigned as follows:

Physical track:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ECC track:	1a		2a		3a		4a		5a		6a		7a		0a		8a	
		7b		6b		5b		4b		3b		2b		1b		0b		8b

11. Format of Tape

The recorded area of tape between BOT and EOT shall be partitioned by the following marks and gaps:

- (1) Density-identification mark
- (2) ID-separator mark
- (3) Interblock gap
- (4) Erase gap
- (5) Tape mark

The marks and gaps are defined by an all ONEs or tone pattern written in groupings of tracks called zones. The tone shall be written on tape as the repeated 6-bit pattern 100000.

11.1 Zones. The 18 tracks shall be divided into six distinct zones:

- Zone A: Tracks 1, 7, 13
- Zone B: Tracks 2, 8, 14
- Zone C: Tracks 3, 9, 15
- Zone D: Tracks 4, 10, 16
- Zone E: Tracks 5, 11, 17
- Zone F: Tracks 6, 12, 18

11.2 Density-Identification Mark. The density-identification mark shall be characterized by:

- All ONEs in zones A, C, F
- Tone in zones B, D, E.

Its length shall be:

Nominal: 2375 mm (94 in)

Minimum: 2250 mm (89 in)

Maximum: 3060 mm (120 in)

The density-identification mark shall be the first recording on the tape.

11.3 ID-Separator Mark. The ID-separator mark shall be characterized by:

All ONEs in all zones.

Its length shall be:

Nominal: 2.0 mm (0.0787 in)

Minimum: 1.9 mm (0.0748 in)

Maximum: 2.1 mm (0.0827 in)

The ID-separator mark shall directly follow the density-identification mark; it separates the density-identification mark from the succeeding interblock gap.

11.4 Interblock Gap. The interblock gap shall be characterized by:

All ONEs in zones A, D, F

Tone in zones B, C, E.

Its length shall be:

Nominal: 2.0 mm (0.079 in)

Minimum: 1.6 mm (0.063 in)

Maximum: 3.0 mm (0.118 in)

Any discontinuity across all tracks in an interblock gap (such as caused by a stop/start operation) shall not be greater than 0.03 mm (0.0012 inch). Such discontinuity shall not occur within 0.5 mm (0.02 inch) before the preamble of a recorded data block or within 0.5 mm (0.02 inch) after the postamble of such a block.

An interblock gap shall be recorded immediately after the ID-separator mark. There shall be an interblock gap recorded before and after each recorded data block, each erase gap, and each tape mark, except after the last tape mark on the tape.

11.5 Erase Gap. The erase gap shall be characterized by:

All ONEs in zones B, C, F

Tone in zones A, D, E.

Erase gaps shall be written over a length of tape where an unsuccessful write operation occurred, or when an erase-gap instruction is given.

11.5.1 Normal-Erase Gap. The length of a normal-erase gap shall be:

Nominal: 7.8 mm (0.307 in)

Minimum: 7.4 mm (0.291 in)

Maximum: 8.2 mm (0.323 in)

Up to 20 successive normal-erase gaps, separated by interblock gaps, are permitted to be written to cover a defect area.

11.5.2 Extended-Erase Gap. The length of an extended-erase gap shall be:

Maximum: 200 mm (7.87 in)

The extended-erase gap shall be recorded when a normal-erase gap, or the following interblock gap, is not recognized as such. Within an extended-erase gap, partial interblock gaps of less than 1 mm (0.04 inch) are permitted to appear.

11.6 Tape Mark. The tape mark shall be characterized by:

All ONEs in zones B, D, E

Tone in zones A, C, F.

The length of each tape mark shall be:

Nominal: 1.0 mm (0.039 in)

Minimum: 0.7 mm (0.028 in)

Maximum: 1.3 mm (0.051 in)

11.7 Summary of Mark and Gap Codes. The following chart summarizes the codes for marks and gaps:

Mark / Gap	Zones					
	A	B	C	D	E	F
Density-identification mark	1	T	1	T	T	1
ID-separator mark	1	1	1	1	1	1
Interblock gap	1	T	T	1	T	1
Erase gap	T	1	1	T	T	1
Tape mark	T	1	T	1	1	T

11.8 Mark Merge. The tape mark or erase gap shall have a 36-bit cell merge with the interblock gap. For example, when an interblock gap precedes a tape mark, the tone in zones B and E of the interblock gap shall be extended 18 bits into the all ONEs area of the tape mark. In a similar way, the tones in zones A and F of the tape mark shall start 18 bits early in the all ONEs area of the interblock gap. The symmetric extensions of tone ensure a 36-bit tone overlap area at the boundary between erase gaps or tape marks and interblock gaps.

11.9 Recording Area. The recording area shall be bounded by BOT and EOT, as shown in Figure 9. BOT shall begin within 1.34 meters (53 inches) from the leader block. The density-identification mark shall end within 3.28 meters (129 inches) from the leader block. EOT shall be greater than 4.3 meters (169 inches) from the tape-to-hub junction. The total length of tape in the cartridge shall be at least 165 meters (541 feet).

12. Format of Data

Prior to recording, the data bytes shall be arranged in groups, called data frames, complete with computed error-correcting-code (ECC) bytes. The data so arranged and the ECC bytes shall then be recorded on tape according to an 8/9 group-code encoding scheme (see Section 15, Recording of Bytes on Tape).

12.1 Data Frame. A frame shall be a logical section across all 18 tracks containing logically related bytes. Each byte in a frame is recorded along a track. The data frame containing 14 data bytes and four ECC bytes is illustrated in Figure 10. The data bytes shall be placed in the frame with the first seven bytes written in the odd-numbered tracks 1 to 13, and the second seven bytes in the even-numbered tracks 2 to 14. The four bytes of ECC shall be generated according to the rules in Section 14.

12.2 Data Bytes. The data bytes consist of:

- (1) User bytes
- (2) Pad bytes
- (3) Block-ID bytes.

12.2.1 User Bytes. User bytes are 8-bit bytes at the disposal of the user of a tape cartridge for the recording of information to be interchanged, stored, or both.

Bits b_1 – b_7 correspond to the bit assignments for 7-bit ASCII characters (ANSI X3.4-1986). Bit b_8 shall be a zero bit when the seven bits b_1 – b_7 represent a 7-bit ASCII character.

Binary weight	—	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Bit designation	—	b_7	b_6	b_5	b_4	b_3	b_2	b_1
Bit position in the byte	8	7	6	5	4	3	2	1

Each of the bits b_1 – b_8 can be either a ZERO or a ONE when the representation is coded in accordance with a standard that permits such encoding, as agreed upon by the interchange parties.

Binary weight	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Bit designation	b_8	b_7	b_6	b_5	b_4	b_3	b_2	b_1
Bit position in the byte	8	7	6	5	4	3	2	1

12.2.2 Pad Bytes. Pad bytes are 8-bit bytes that have a bit pattern consisting of eight ZEROS, encoded as the 9-bit (one encoded byte) sequence 011001011.

12.2.3 Block-ID Bytes. A four-byte block ID shall be written after the last user data byte. The block ID is included as data in the recorded-block format, as shown in Figures 11 and 12. The 32 bits are numbered from 1

(most significant) to 32 (least significant). The bytes are written sequentially with the most significant byte (1) recorded first and the least significant byte (4) recorded last. These bits shall have the following values:

(1) *Bit 1*. This bit shall be a ZERO.

(2) *Bits 2–8*. These bits shall express in binary notation the value of a physical-position indicator. This value shall be the largest positive integer satisfying the condition:

$$1 \leq [62.5 \times ((625 + R_1^2 - R^2)^{0.5})/R - 25/R_1] \leq 91$$

where:

R_1 is the initial radius (mm) of a full cartridge reel and R is the current radius (mm) of a cartridge reel. The purpose of the physical position indicator is to provide a coarse, fast indication of the location of the data without reading the data or all block-ID bytes. The [] symbols indicate rounding up to the next positive integer.

(3) *Bits 9–12*. These bits shall be ZEROS.

(4) *Bits 13–32*. These bits shall express in binary notation a count that is increased by 1 for each data block and each tape mark. The count is set to 0 for the first data block or tape mark following the initial interblock gap. These 32 bits shall be assigned to the following positions:

Byte sequence	1	2	3	4
Bits	1 to 8	9 to 16	17 to 24	25 to 32
Position in byte	8 to 1	8 to 1	8 to 1	8 to 1

13. Format of Recorded Block

The recorded block format is shown in Figure 11.

13.1 Preamble. Preceding the data in each recorded block, a preamble shall be written consisting of a minimum of nine and a maximum of 13 control frames of the 9-bit (one encoded byte) sequence 11111111 in all tracks.

13.2 Beginning-of-Data Mark (BDM). The beginning-of-data mark shall consist of two successive repetitions of the sync-control frame (see 13.4).

13.3 Prefix Frames. Two prefix frames shall be recorded at the beginning of a block. Their function is to provide the required pad characters for the adaptive cross-parity ECC before the first data frame. The data and ECC portion of the prefix frames shall be all-ZEROS data recorded as the 9-bit (one encoded byte) sequence 011001011.

13.4 Sync/Resync Control Frame. The sync/resync control frame shall be one set of the 9-bit (one encoded byte) sequence 100010001 in each of the 18 parallel tracks. The resync-control frame shall be interleaved in the recorded block after every 71 frames (prefix, data, residual, and completion). The first sync-control frame of the end-of-data mark shall take the place of the resync-control frame in case of overlap.

13.5 Residual Frame 1. The residual frame 1 shall contain the last data bytes (including the block ID) and pad bytes of the block, provided there are 12 or 13 residual data bytes. If there are less than 12, no residual frame 1 is written.

13.6 Residual Frame 2. The residual frame 2 shall contain any remaining data bytes, block-ID bytes, pad bytes if required, the residual byte, and the two-byte CRC code. The residual byte and CRC bytes shall be recorded in physical tracks 10, 12, and 14, respectively.

13.7 Completion Frames. Two completion frames shall be recorded at the end of a block. Their function is to provide pad characters to complete the cross-parity check of the data and residual frames. The data portion shall be all-ZEROS data recorded as the 9-bit (one encoded byte) sequence 011001011. The ECC bytes shall be generated in the normal way (see Section 14).

13.8 End-of-Data Mark (EDM). The end-of-data mark shall consist of two successive repetitions of the sync-control frame. The first sync-control frame of the EDM shall take the place of the resync-control frame in case of overlap. There shall never be more than two successive sync-control frames.

13.9 Postamble. Following the data, the residual frames, the completion frames, and the EDM, a postamble shall be written consisting of a minimum of nine and a maximum of 13 control frames of the 9-bit (one encoded byte) sequence 11111111 in all tracks.

13.10 Residual Byte. The residual byte shall be recorded in track 10 of residual frame 2. Bits are numbered from 1 (most significant) to 8 (least significant):

- (1) *Bits 1–2.* These bits are unspecified; they can be ONE or ZERO.
- (2) *Bits 3–4.* These bits shall be ONES.
- (3) *Bits 5–8.* These bits shall express in binary notation the total number of pad bytes in the residual frames.

The allocation of bits to the position in the residual byte shall be:

Bits	1 to 8
Bit position in the byte	8 to 1

13.11 CRC Bytes. The 16-bit cyclic redundancy check (CRC) character shall be represented by two bytes recorded in tracks 12 and 14 of the residual frame 2. The CRC character shall be computed from the generator polynomial

$$X^{16} + X^{15} + X^8 + X + 1$$

as shown in Figure 13.

The CRC is computed sequentially over all data bytes, pad bytes, and the residual byte; it does not include the ECC bytes. The bits within the byte shall be processed starting with bit 1, the least-significant bit, and ending with bit 8, the most-significant bit.

The allocation of bits to the position in the two CRC bytes shall be:

<u>Byte Sequence</u>	<u>CRC Byte 1</u> <u>Track 12</u>	<u>CRC Byte 2</u> <u>Track 14</u>
Bits in the shift register	9 to 16	1 to 8
Bit position in the CRC byte	8 to 1	8 to 1

13.12 Frame-Format Summary. Figure 12 summarizes the different frame formats.

14. Error-Correcting Code (ECC)

The error-correcting code yields two types of check bits:

- (1) Diagonal redundancy check (DRC)
- (2) Vertical redundancy check (VRC).

Computation of the DRCs and VRCs starts with the prefix frames and ends with the completion frames. The computation excludes the resync frames.

The 18 tracks are grouped into two sets. Set A consists of the nine odd-numbered tracks and set B consists of the nine even-numbered tracks. In Figure 14 the two sets are shown side by side with a symmetrically ordered arrangement of tracks.

In the following subsections, A_{n_m} and B_{n_m} denote the m th bit in the n th track of sets A and B, respectively. Tracks 1 to 7 in each set contain data, and tracks 0 and 8 are check tracks.

14.1 Diagonal Redundancy Check (DRC). The two DRCs shall be recorded in tracks 0a and 0b, respectively. The bits in each of these tracks shall be computed from the bits in the other tracks, except tracks 8a and 8b. The m th bit in each of these tracks is specified by:

$$A0_m = (A1_{m-1} + A2_{m-2} + \dots + A7_{m-7} + B7_{m-8} + B6_{m-9} + \dots + B0_{m-15}) \text{ modulo } 2$$

$$B0_m = (B1_{m-1} + B2_{m-2} + \dots + B7_{m-7} + A7_{m-8} + A6_{m-9} + \dots + A0_{m-15}) \text{ modulo } 2$$

14.2 Vertical Redundancy Check (VRC). The two VRCs shall be recorded in tracks 8a and 8b, respectively. The bits in each of these tracks shall be computed from the bits of the tracks in their respective groups. The m th bit in each of these tracks is specified by:

$$A8_m = (A0_m + A1_m + \dots + A7_m) \text{ modulo } 2$$

$$B8_m = (B0_m + B1_m + \dots + B7_m) \text{ modulo } 2$$

14.3 ECC Format. The ECC bits in each track shall be grouped into 8-bit bytes to be encoded into 9-bit bytes, in accordance with the data-frame format (see Figure 10). The physical-to-ECC track relationship is given in 10.6, Identification of Track.

15. Recording of Bytes on Tape

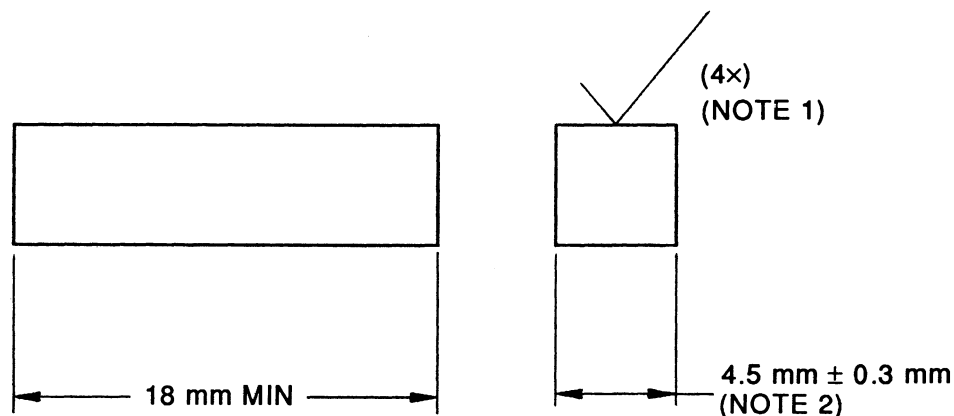
15.1 Byte Translation. The data prepared as described in Sections 9–14 shall be recorded on tape as follows:

Each 8-bit byte shall be translated according to Table 2, and written on the tape as nine consecutive bits. The highest numbered bit position (most significant digit) is closest to BOT.

15.2 Capacity of the Recorded Block. The data portion of a recorded block shall contain, in single-byte characters, a minimum of 1 byte and a maximum of 32 768 bytes. However, larger blocks may be used by agreement between the interchange parties.

15.3 Maximum Data Density. Due to the insertion of ECC bytes, the 8-bit to 9-bit conversion, and the resync-control frame, the maximum density of recorded data is:

$$14 \times 972 \times (1/8) \times (8/9) \times (71/72) = 1491 \text{ cpm} (37\,871 \text{ cpi})$$



NOTES:

(1) Surface finish all four sides to N2, 0.05 μm (2.0 μin), or better.

(2) Must be square within 0.05 mm (0.002 in).

(3) Material:

Polycrystalline ferrite:	single phase
Grain size:	7 μm – 8 μm (276 μin – 315 μin)
Density:	5.32 g/cm ³ (3.08 oz/in ³) minimum
Composition by weight:	ZnO 22%
	NiO 11%
	Fe ₂ O ₃ 67%

(4) This material is available as Sumitomo H4R2 or H4R3 from Sumitomo Metal Division, Torrance, California, or equivalent.

Figure 1
Ferrite-Wear Bar

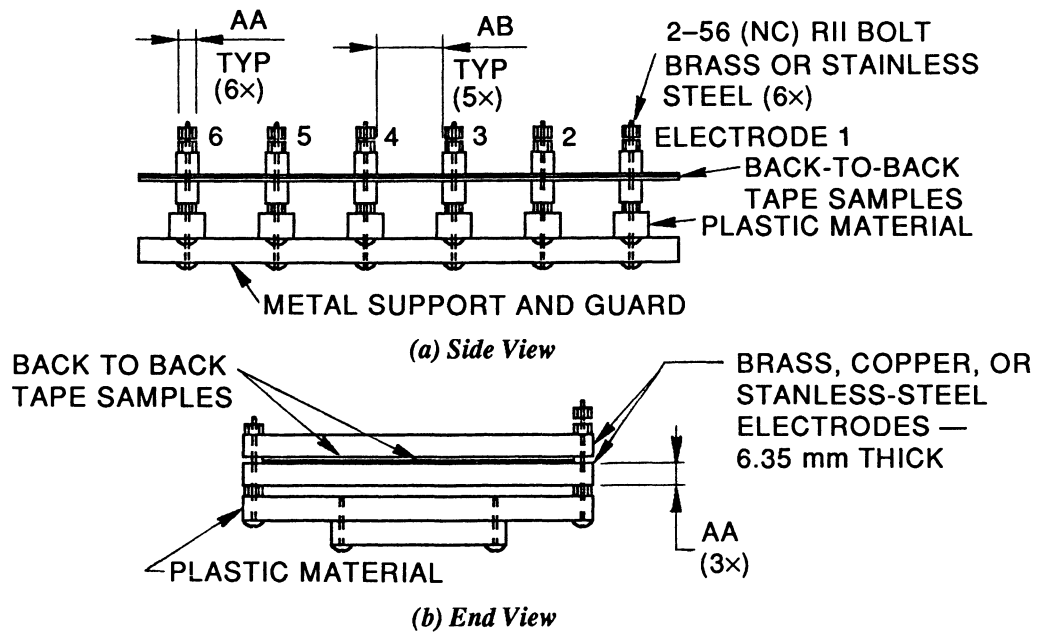


Figure 2
Tape-Resistance-Measurement Electrodes

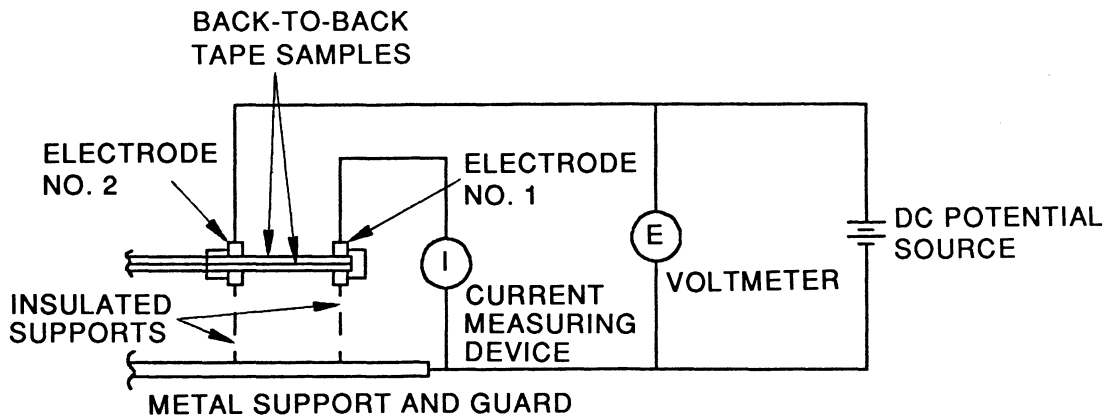
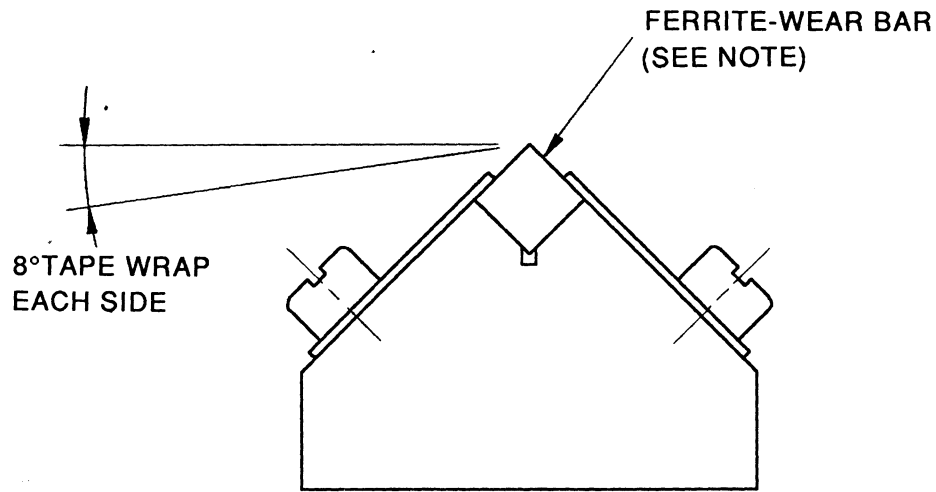
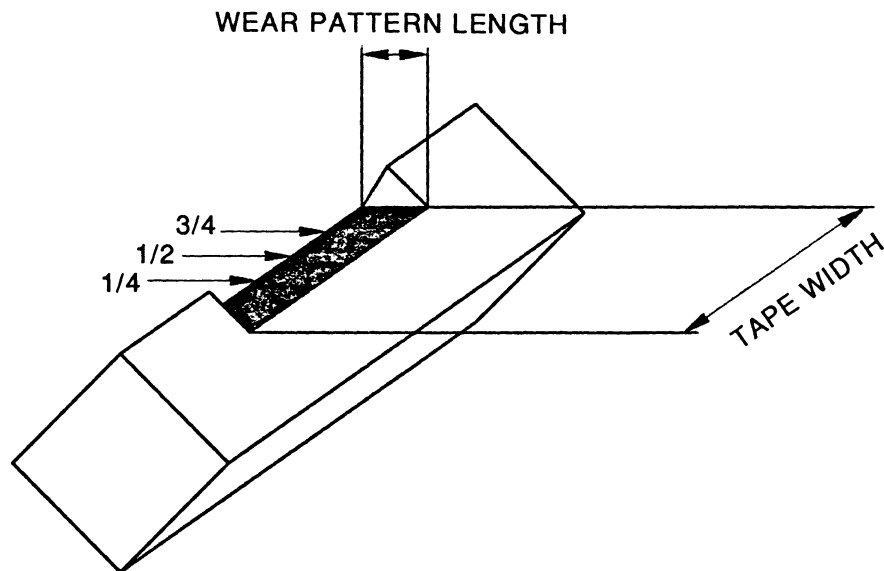


Figure 3
Tape-Resistance-Measurement Circuit



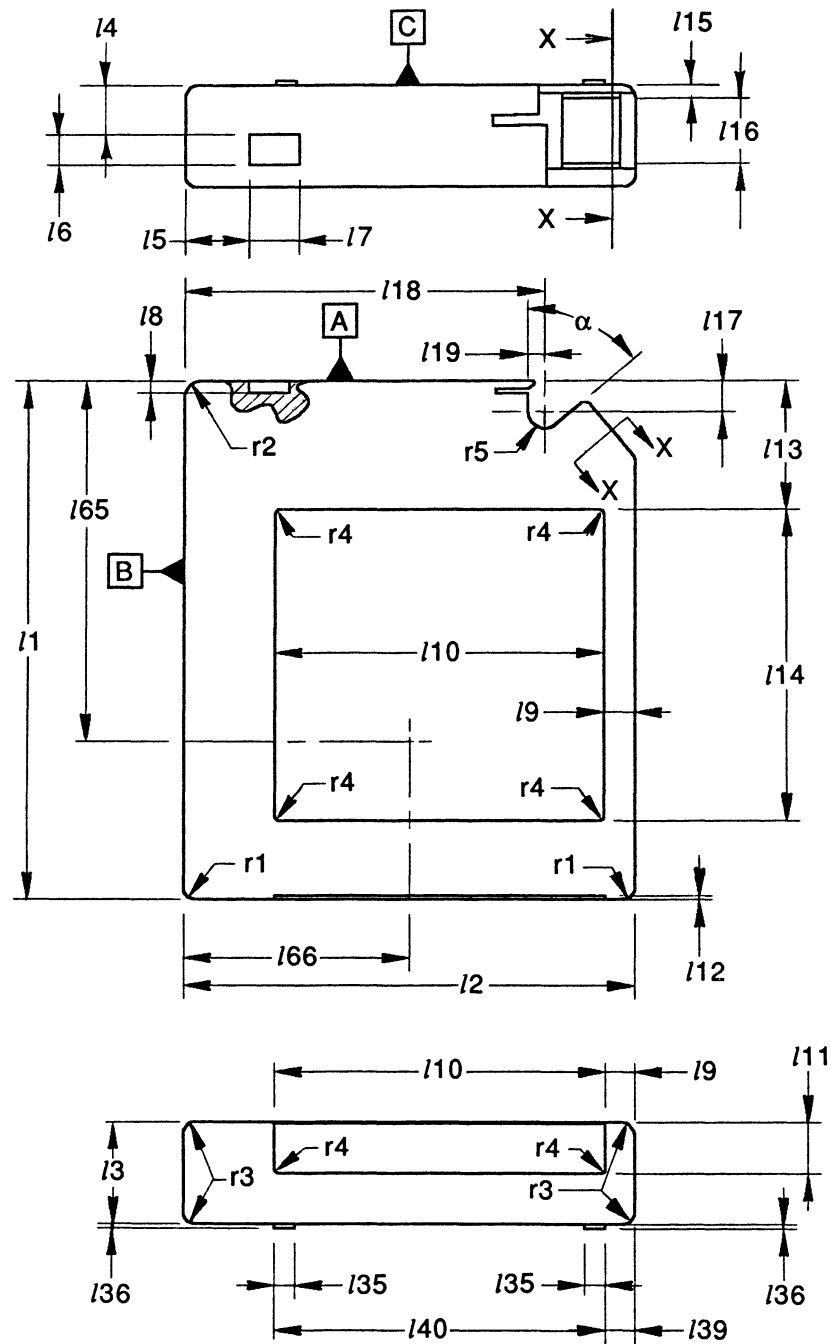
NOTE: Test edge shall be free of chips or voids greater than $1\text{ }\mu\text{m}$ ($39\text{ }\mu\text{in}$). The radius of the test edge shall not be greater than $13\text{ }\mu\text{m}$ ($512\text{ }\mu\text{in}$).

Figure 4
Wear-Bar Holding Fixture



NOTE: The amount of wear is exaggerated for clarity.

Figure 5
Typical Wear Pattern: Ferrite Bar Following Abrasivity Test Illustrating Three Locations for Wear-Length Measurement



(a) Top and Ends of Tape Cartridge

NOTE: Figures 6(a)-(h) constructed using third-angle projection

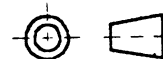
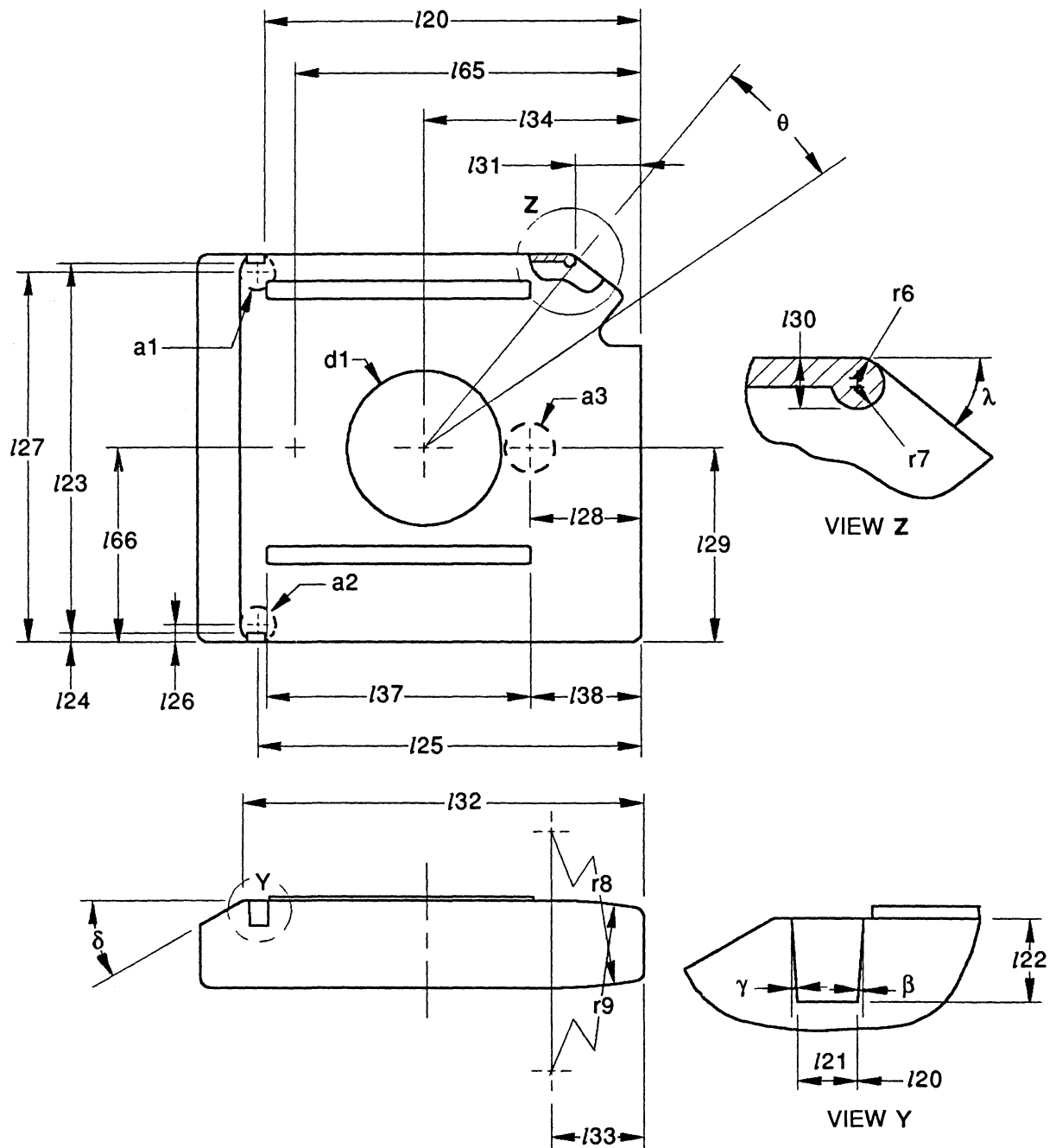
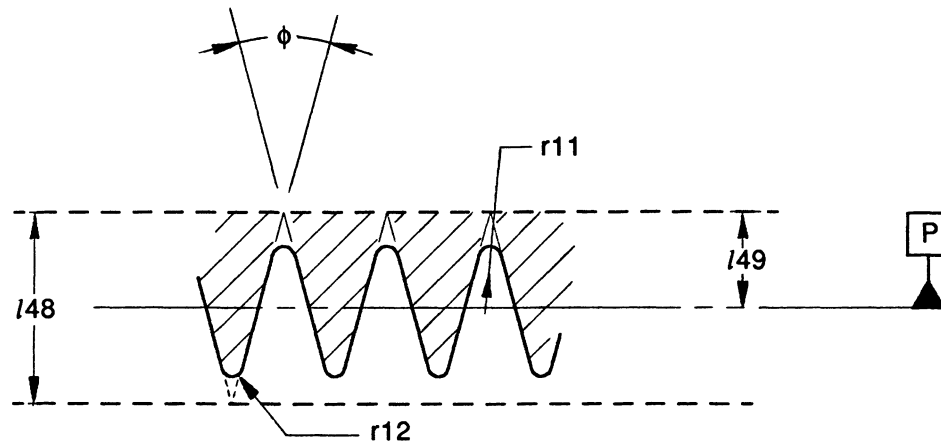


Figure 6
Mechanical Requirements of the Tape Cartridge



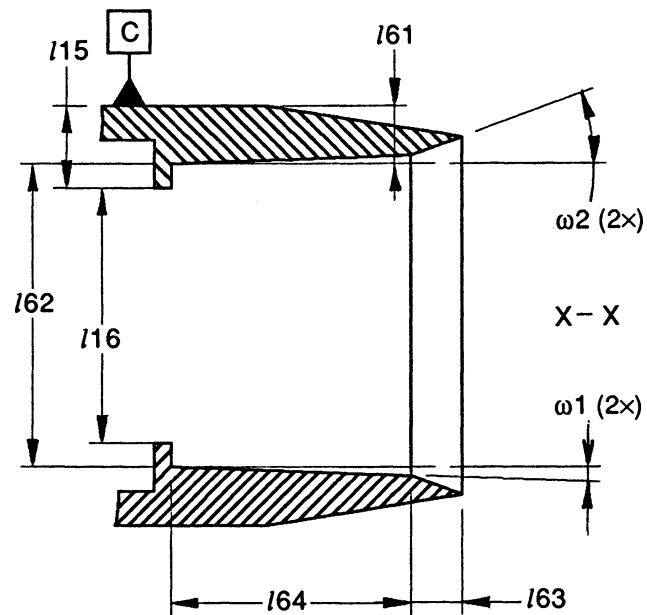
(b) Bottom and Side of Tape Cartridge

Figure 6
Mechanical Requirements of the Tape Cartridge (continued)



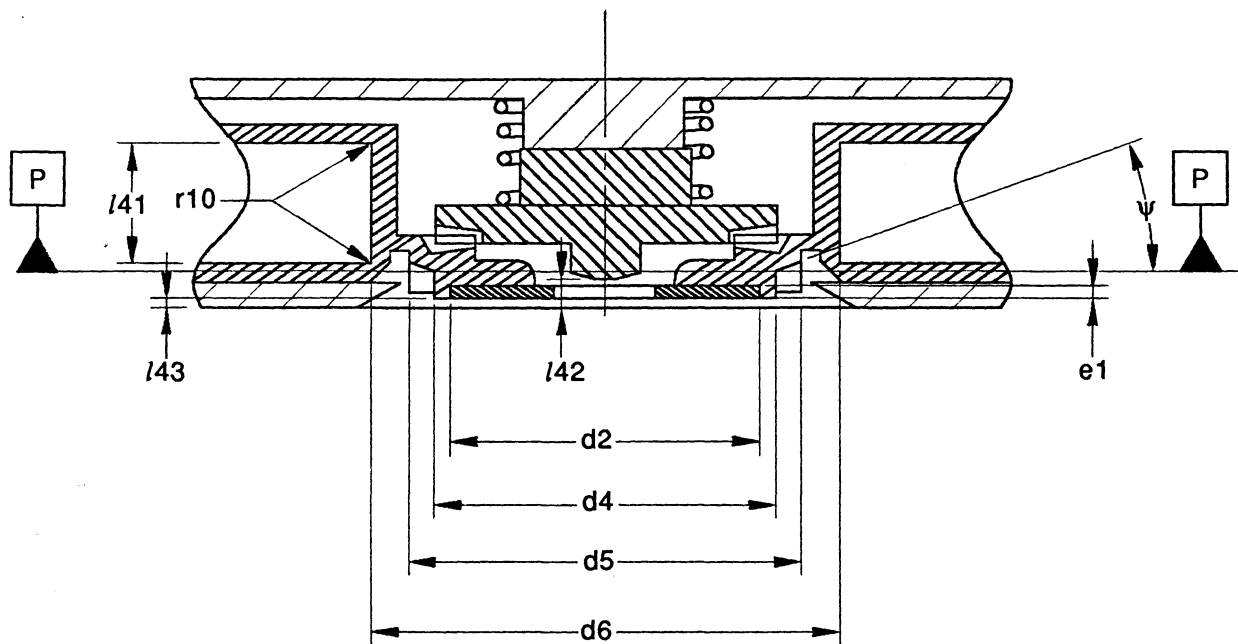
NOTE: Total of 60 gear teeth.

*(c) View Taken at 41-mm
(1.614-in) Reference Diameter
Showing Gear-Tooth Profile Only*

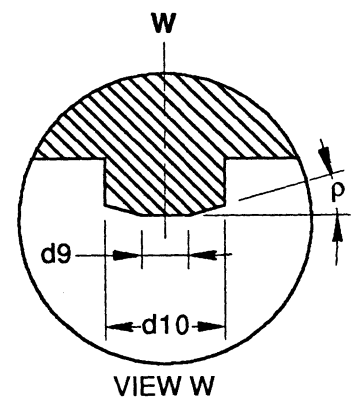


(d) Cross-Section View of Leader-Block Opening

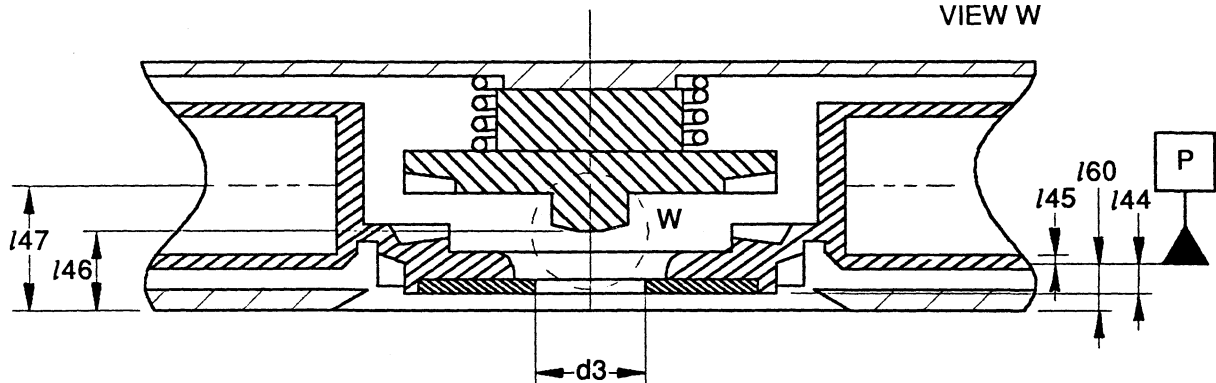
Figure 6
Mechanical Requirements of the Tape Cartridge (continued)



(e) Cartridge in Hand

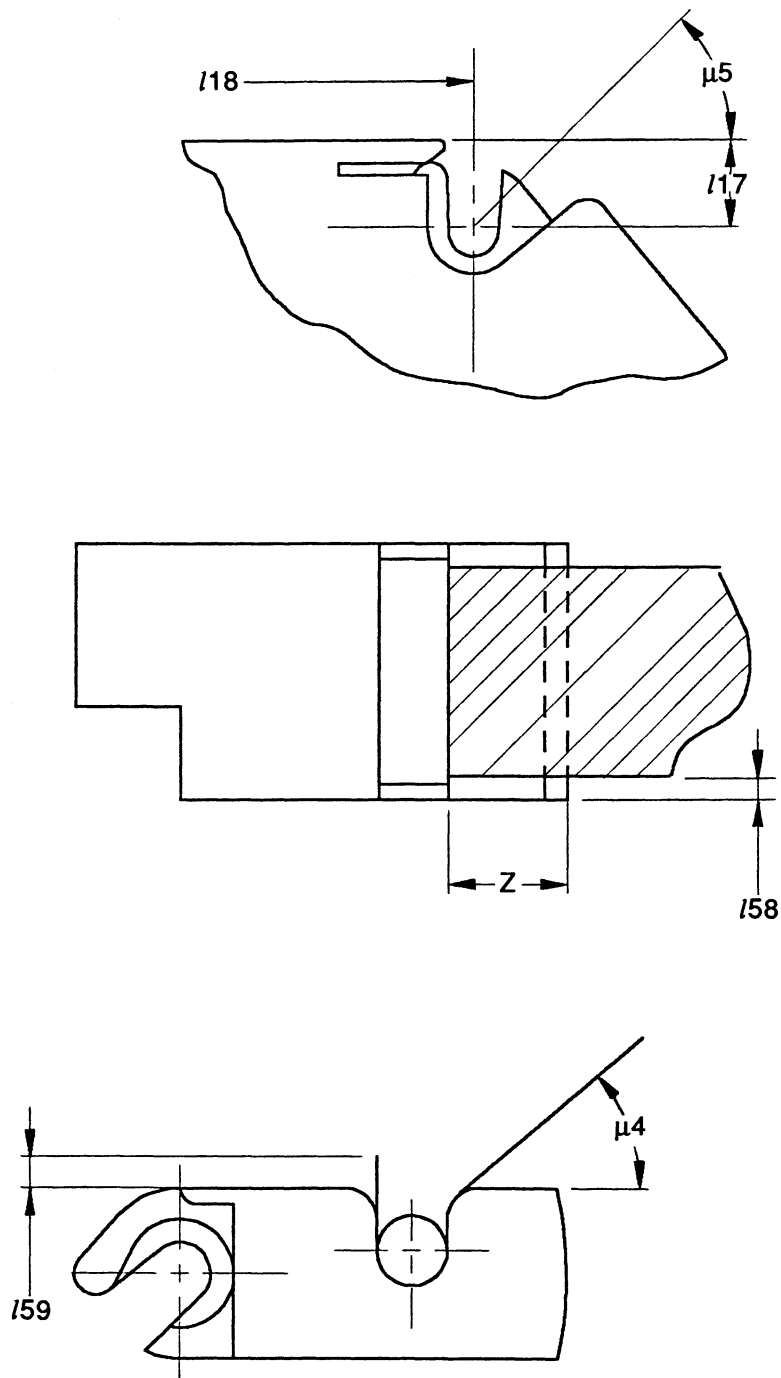


VIEW W



(f) Cartridge in Machine

Figure 6
Mechanical Requirements of the Tape Cartridge (continued)



(g) Leader Block Tape Attachment

Figure 6
Mechanical Requirements of the Tape Cartridge (continued)

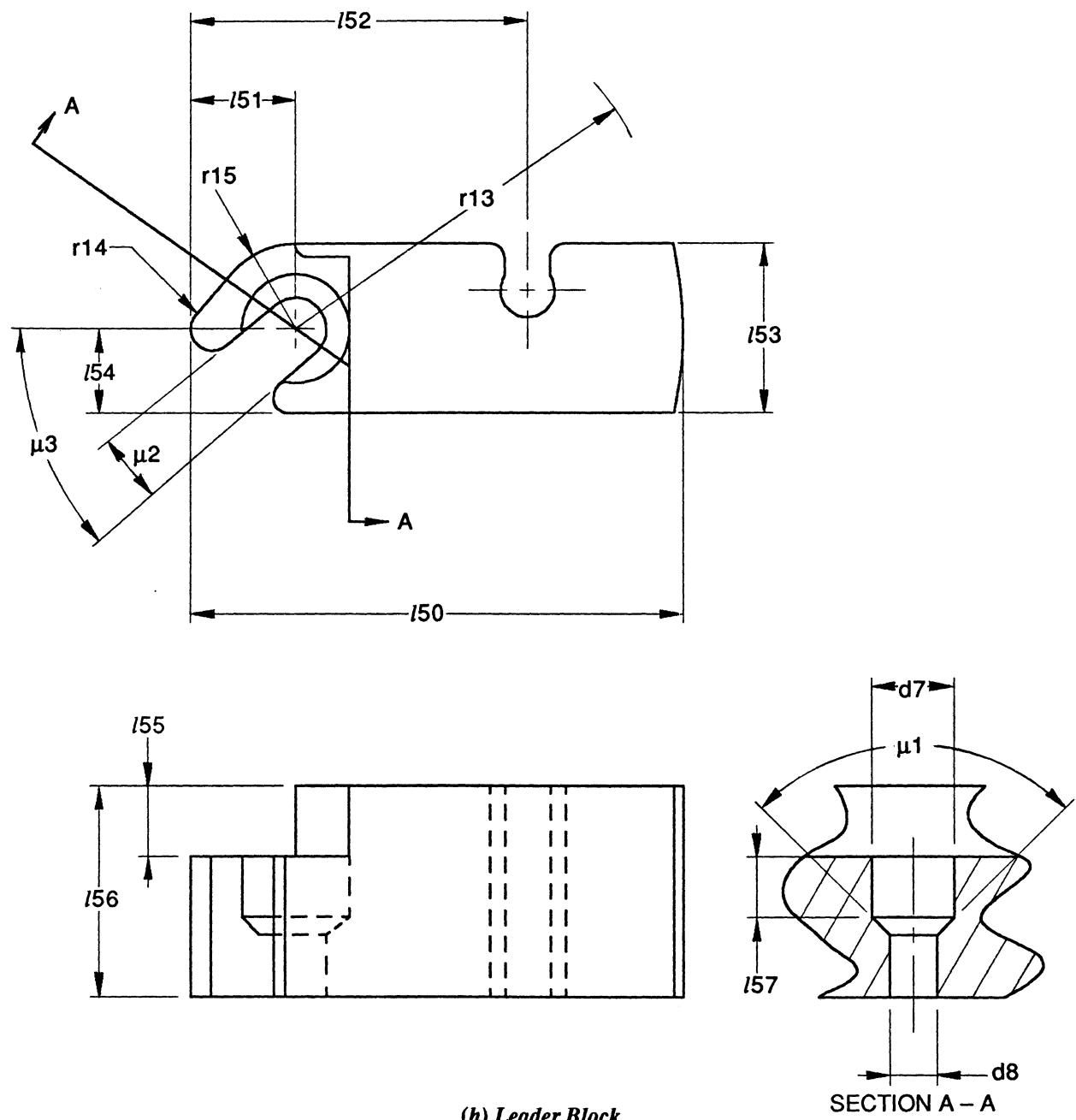


Figure 6
Mechanical Requirements of the Tape Cartridge (continued)

Table 1
Key to Figures 6a-6g

Symbol	Metric (mm)		English (in)	
	Dimension	Tolerance	Dimension	Tolerance
I1	125.00	±0.32	4.921	± 0.013
I2	109.00	±0.32	4.291	± 0.013
I3	24.50	+0.50 -0.32	0.965	+ 0.019 -0.013
I4	11.80		0.465	
I5	15.60		0.614	
I6	7.40		0.291	
I7	12.00		0.472	
I8	2.55	min	0.1004	min
I9	7.00		0.276	
I10	80.00	+0.30 -0.16	3.1496	+0.0118 -0.0063
I11	12.30		0.484	
I12	0.50		0.020	
I13	31.00		1.220	
I14	75.00	+0.30 -0.16	2.9528	+0.0118 -0.0063
I15	4.70		0.185	
I16	14.90	±0.32	0.587	±0.013
I17	7.50		0.295	
I18	87.10		3.429	
I19	4.00		0.157	
I20	106.00		4.173	
I21	5.00		0.197	
I22	7.00		0.276	
I23	104.00		4.094	
I24	2.50		0.098	
I25	108.50		4.272	
I26	3.50		0.138	
I27	105.50		4.154	
I28	31.25		1.230	
I29	54.50		2.146	
I30	3.30		0.130	
I31	18.40		0.724	
I32	113.2	±0.3	4.457	±0.012
I33	26.00		1.024	
I34	61.00		2.402	
I35	5.00		0.197	
I36	1.00	±0.16	0.0394	±0.0063
I37	74.50		2.933	
I38	31.00		1.220	
I39	7.50	±0.32	0.295	±0.013
I40	79.50		3.130	
I41	13.05	+0.20 -0.10	0.5138	+0.0079 -0.0039
I42	1.9	+1.4 -0.9	0.075	+0.055 -0.035
I43	0.4	+1.0 -0.5	0.016	+0.039 -0.020
I44	2.27	±0.12	0.0894	±0.0047
I45	0.65	±0.09	0.0256	±0.0035
I46	8.1	±0.2	0.3189	±0.0079
I47	12.25	ref	0.482	ref
I48	4	basic	0.1575	basic
I49	2	basic	0.0787	basic
I50	31.80	±0.04	1.2520	±0.0016
I51	6.8	±0.1	0.2677	±0.0039
I52	21.8	±0.2	0.8583	±0.0079
I53	10.93	+0.06 -0.08	0.4303	±0.0024 -0.0031

Tolerance is ±0.25 mm (0.010 in) unless otherwise noted.

Table 1
Key to Figures 6a-6g (continued)

Symbol	Metric (mm)		English (in)	
	Dimension	Tolerance	Dimension	Tolerance
l54	5.46	±0.10	0.2150	±0.0039
l55	6.00		0.236	
l56	16.5	+0.0 -0.2	0.6496	+0.0000 -0.0079
l57	5.2	±0.2	0.2047	±0.0079
l58	1.90	±0.26	0.075	±0.010
l59	2.5	max	0.10	max
l60	5.04	±0.20	0.1984	±0.0079
l61	3.9	±0.5	0.154	±0.020
l62	16.9	+0.5 -0.4	0.665	+0.020 -0.016
l63	3.0	±0.5	0.118	±0.020
l64	11.6	±0.5	0.457	±0.020
l65	86.9	ref	3.421	ref
l66	54.5	ref	2.146	ref
r1	R3.00	max	R0.1181	max
r2	R4.00	max	R0.1575	max
r3	R3.00	min	R0.1181	min
r4	R1.00	max	R0.0394	max
r5	R4.00		R0.157	
r6	R1.50		R0.059	
r7	R1.50		R0.059	
r8	R145.50		R5.728	
r9	R145.50		R5.728	
r10	R0.08	max	R0.0031	max
r11	R0.25	max	R0.0098	max
r12	R0.2	±0.1	R0.0079	±0.0039
r13	R25.00		R0.984	
r14	R1.4	±0.2	R0.0551	±0.0079
r15	R5.50	ref	R0.217	ref
a1	Ø10.00		Ø0.394	
a2	Ø10.00		Ø0.394	
a3	Ø14.00		Ø0.551	
d1	Ø43.50	+2.00 -0.25	Ø1.713	+0.079 -0.010
d2	Ø35.0	+0.2 -1.2	Ø1.378	+0.008 -0.047
d3	Ø11.15	±0.05	Ø0.4390	±0.0020
d4	Ø36.0	+0.5 -0.0	Ø1.417	+0.020 -0.000
d5	Ø41.00		Ø1.614	
d6	Ø50.0	+0.0 -0.2	Ø1.9685	+0.0000 -0.0079
d7	Ø7.0	±0.2	Ø0.2756	±0.0079
d8	Ø4.0	±0.2	Ø0.1575	±0.0079
d9	Ø2.0	±0.5	Ø0.079	±0.020
d10	Ø10.0	±0.2	Ø0.3937	±0.0079
e1	1.51	±0.10	0.059	±0.004

Tolerance is ±0.25 mm (0.010 in) unless otherwise noted.

R - Radius dimension

Ø - Diameter dimension

Table 1
Key to Figures 6a-6g (continued)

Symbol	Dimension	Tolerance
α	50°	$\pm 1^\circ$
β	1°30'	$\pm 0^\circ 30'$
γ	2°	$\pm 0^\circ 30'$
δ	30°	$\pm 0^\circ 30'$
θ	16°	$\pm 0^\circ 30'$
λ	40°	$\pm 0^\circ 30'$
ρ	15°	$\pm 2^\circ$
ϕ	30°	ref
ψ	11°3'	$\pm 0^\circ 5'$
$\mu 1$	90°	$\pm 2^\circ$
$\mu 2$	8°	$+0^\circ$
		-3°
$\mu 3$	44°	$+0^\circ$
		-3°
$\mu 4$	38°	$\pm 2^\circ$
$\mu 5$	48°	$\pm 3^\circ$
$\omega 1$	1°	$\pm 0^\circ 30'$
$\omega 2$	20°	$\pm 2^\circ$

Tolerance is ± 0.25 mm (0.010 in) unless otherwise noted.

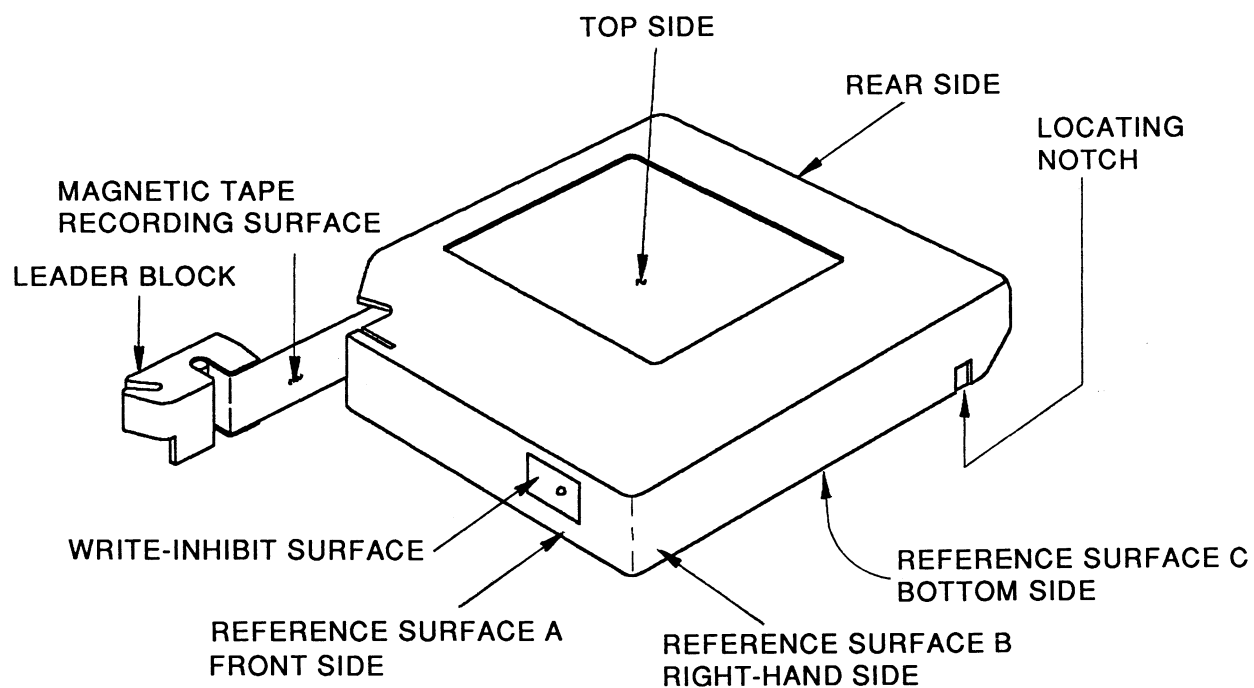
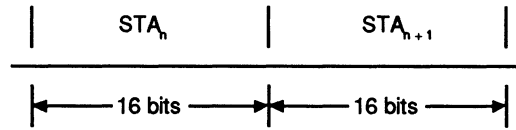


Figure 7
Tape Cartridge Assembly



$$100 \times (|STA_n - STA_{n+1}| / STA_n) \leq 1.6\%$$

Figure 8
Rate of Change for Two Bit-Cell Length Measurements

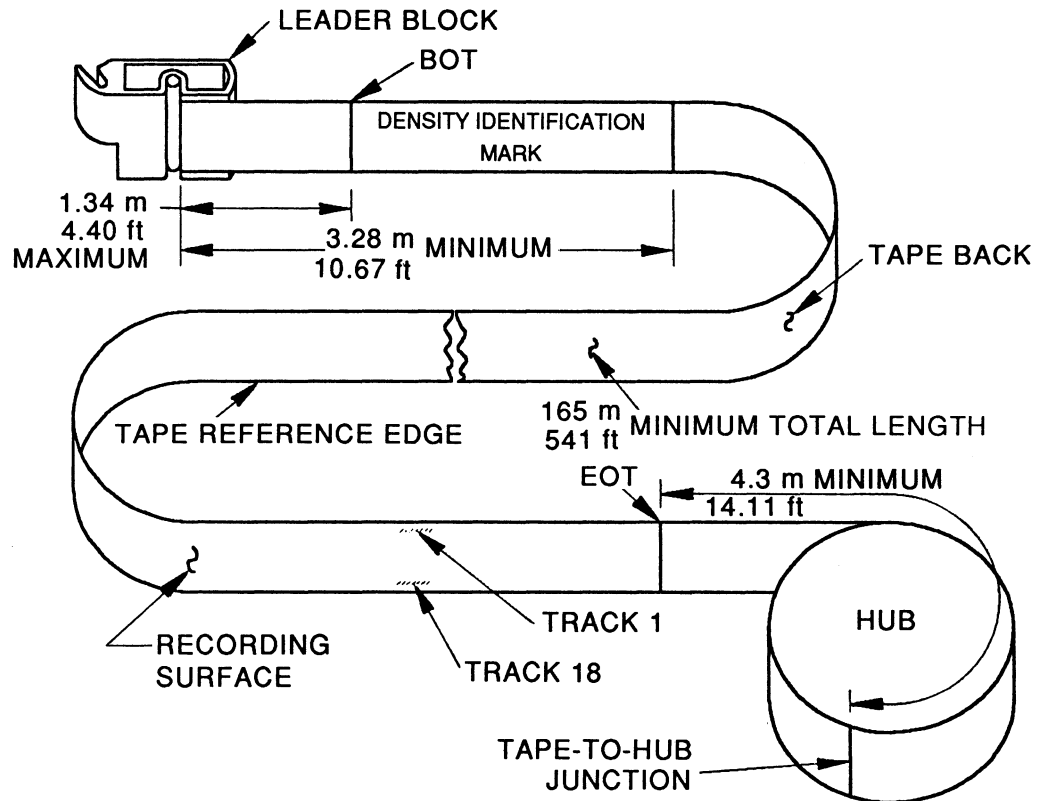


Figure 9
Usable Recording Area

Phy Tk	Data-Byte Sequence	ECC Data Group A	ECC Data Group B	Encoded Byte
1	1	b b b b b b b b		x x x x x x x x
2	8		b b b b b b b b	x x x x x x x x
3	2	b b b b b b b b		x x x x x x x x
4	9		b b b b b b b b	x x x x x x x x
5	3	b b b b b b b b		x x x x x x x x
6	10		b b b b b b b b	x x x x x x x x
7	4	b b b b b b b b		x x x x x x x x
8	11		b b b b b b b b	x x x x x x x x
9	5	b b b b b b b b		x x x x x x x x
10	12		b b b b b b b b	x x x x x x x x
11	6	b b b b b b b b		x x x x x x x x
12	13		b b b b b b b b	x x x x x x x x
13	7	b b b b b b b b		x x x x x x x x
14	14		b b b b b b b b	x x x x x x x x
15		p p p p p p p p		x x x x x x x x
16			p p p p p p p p	x x x x x x x x
17		p p p p p p p p		x x x x x x x x
18			p p p p p p p p	x x x x x x x x
Bit position in the byte		8 7 6 5 4 3 2 1	8 7 6 5 4 3 2 1	9 8 7 6 5 4 3 2 1

NOTE: The highest-numbered bit position (most significant digit) is closest to BOT.

b - Data bit

p - ECC bit

x - 8/9 encoded bit

Figure 10
Format of Data-Frame

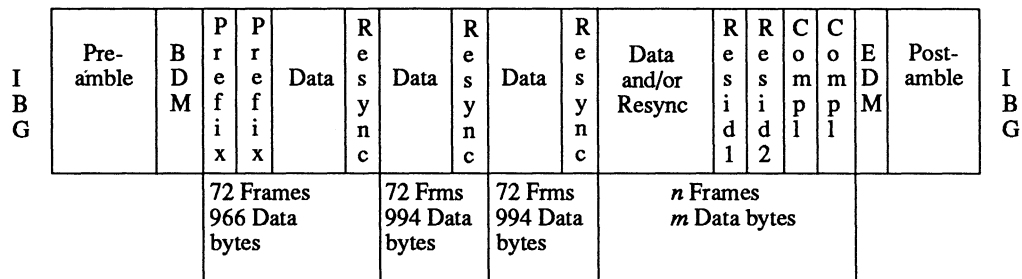
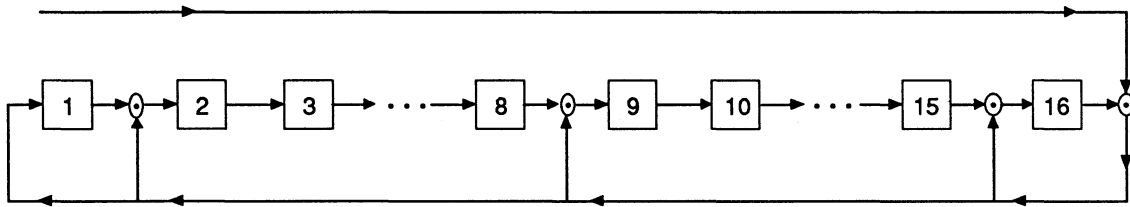


Figure 11
Format of Recorded-Block

Physical Track	Prefix Frame	Data Frame	Residual Frame 1	Residual Frame 2	Completion Frame	Sync/ Resync
1	9 bytes of ZEROs	7 bytes of data	7 bytes of data	7 bytes of data or pad	7 bytes of ZEROs	Sync pattern 18x
3						
5						
7						
9						
11	9 bytes of ZEROs	7 bytes of data	7 bytes of data	7 bytes of data or pad	7 bytes of ZEROs	
13						
15						
17						
19						
2	9 bytes of ZEROs	7 bytes of data	5 bytes of data	4 bytes of data or pad	7 bytes of ZEROs	
4						
6						
8						
10						
12	9 bytes of ZEROs	7 bytes of data	Pad or Data 1 of Pad	Resid byte CRC byte 1 CRC byte 2	7 bytes of ZEROs	
14						
16						
18						
20						

Figure 12
Summary of Frames



NOTE: $\oplus$ indicates modulo two addition.

Figure 13
Shift Register Representation

ECC Track					Physical Track
8a	▽				17
0a	*	*		•	15
1a		*	*		1
2a			*	*	3
3a		*		*	5
4a		*	*	*	7
5a		*	*	*	9
6a		*	*		11
7a		*	*		13
7b		*	*		2
6b		*	*	*	4
5b		*	*	*	6
4b		*	*	*	8
3b	*	*	*	*	10
2b	*	*	*	*	12
1b	*	*	*	*	14
0b	*	*	⊗		16
8b		□			18

- ▽ bit of the VRC – A
- bit of the DRC – A
- bit of the VRC – B
- ⊗ bit of the DRC – B

Figure 14
ECC Organization Format

Table 2
8/9 Group-Code Conversion

8 Bit Byte		Encoded	8 bit Byte		Encoded
Hex	Binary	9 Bit Byte	Hex	Binary	9 Bit Byte
00	00000000	011001011	40	01000000	010001011
01	00000001	011001001	41	01000001	010001001
02	00000010	001001101	42	01000010	010010010
03	00000011	101100011	43	01000011	010010011
04	00000100	011001010	44	01000100	010001010
05	00000101	101100101	45	01000101	010010101
06	00000110	101100110	46	01000110	010010110
07	00000111	101100111	47	01000111	010010111
08	00001000	011001111	48	01001000	010001111
09	00001001	101101001	49	01001001	010011001
0A	00001010	101101010	4A	01001010	010011010
0B	00001011	101101011	4B	01001011	010011011
0C	00001100	011001110	4C	01001100	010001110
0D	00001101	101101101	4D	01001101	010011101
0E	00001110	101101110	4E	01001110	010011110
0F	00001111	101101111	4F	01001111	010011111
10	00010000	001001011	50	01010000	011100101
11	00010001	001001001	51	01010001	001100101
12	00010010	011001101	52	01010010	010110010
13	00010011	100100011	53	01010011	010110011
14	00010100	001001010	54	01010100	010100101
15	00010101	100100101	55	01010101	010110101
16	00010110	100100110	56	01010110	010110110
17	00010111	100100111	57	01010111	010110111
18	00011000	001001111	58	01011000	111100101
19	00011001	100101001	59	01011001	010111001
1A	00011010	100101010	5A	01011010	010111010
1B	00011011	100101011	5B	01011011	010111011
1C	00011100	001001110	5C	01011100	110100101
1D	00011101	100101101	5D	01011101	010111101
1E	00011110	100101110	5E	01011110	010111110
1F	00011111	100101111	5F	01011111	010111111
20	00100000	101001111	60	01100000	011100110
21	00100001	101001101	61	01100001	001100110
22	00100010	001010010	62	01100010	011010010
23	00100011	001010011	63	01100011	011010011
24	00100100	101001110	64	01100100	011000110
25	00100101	001010101	65	01100101	011010101
26	00100110	001010110	66	01100110	011010110
27	00100111	001010111	67	01100111	011010111
28	00101000	101001011	68	01101000	111100110
29	00101001	001011001	69	01101001	011011001
2A	00101010	001011010	6A	01101010	011011010
2B	00101011	001011011	6B	01101011	011011011
2C	00101100	101001010	6C	01101100	110100110
2D	00101101	001011101	6D	01101101	011011101
2E	00101110	001011110	6E	01101110	011011110
2F	00101111	001011111	6F	01101111	011011111
30	00110000	011100011	70	01110000	011100111
31	00110001	001100011	71	01110001	001100111
32	00110010	001110010	72	01110010	011110010
33	00110011	001110011	73	01110011	011110011
34	00110100	010100011	74	01110100	010100111
35	00110101	001110101	75	01110101	011110101
36	00110110	001110110	76	01110110	011110110
37	00110111	001110111	77	01110111	011110111
38	00111000	111100011	78	01111000	111100111
39	00111001	001111001	79	01111001	011111001
3A	00111010	001111010	7A	01111010	011111010
3B	00111011	001111011	7B	01111011	011111011
3C	00111100	110100011	7C	01111100	110100111
3D	00111101	001111101	7D	01111101	011111101
3E	00111110	001111110	7E	01111110	011111110
3F	00111111	001111111	7F	01111111	011111111
Position in byte	8 1	9 1	Position in byte	8 1	9 1

Table 2
8/9 Group-Code Conversion (continued)

8-Bit Byte		Encoded	8-bit Byte		Encoded
Hex	Binary	9-Bit Byte	Hex	Binary	9-Bit Byte
80	10000000	111001011	C0	11000000	110001011
81	10000001	111001001	C1	11000001	110001001
82	10000010	100010010	C2	11000010	110010010
83	10000011	100010011	C3	11000011	110010011
84	10000100	111001010	C4	11000100	110001010
85	10000101	100010101	C5	11000101	110010101
86	10000110	100010110	C6	11000110	110010110
87	10000111	100010111	C7	11000111	110010111
88	10001000	111001111	C8	11001000	110001111
89	10001001	100011001	C9	11001001	110011001
8A	10001010	100011010	CA	11001010	110011010
8B	10001011	100011011	CB	11001011	110011011
8C	10001100	111001110	CC	11001100	110001110
8D	10001101	100011101	CD	11001101	110011101
8E	10001110	100011110	CE	11001110	110011110
8F	10001111	100011111	CF	11001111	110011111
90	10010000	011101001	D0	11010000	011101101
91	10010001	001101001	D1	11010001	001101101
92	10010010	100110010	D2	11010010	110110010
93	10010011	100110011	D3	11010011	110110011
94	10010100	010101001	D4	11010100	010101101
95	10010101	100110101	D5	11010101	110110101
96	10010110	100110110	D6	11010110	110110110
97	10010111	100110111	D7	11010111	110110111
98	10011000	111101001	D8	11011000	111101101
99	10011001	100111001	D9	11011001	110111001
9A	10011010	100111010	DA	11011010	110111010
9B	10011011	100111011	DB	11011011	110111011
9C	10011100	110101001	DC	11011100	110101101
9D	10011101	100111101	DD	11011101	110111101
9E	10011110	100111110	DE	11011110	110111110
9F	10011111	100111111	DF	11011111	110111111
A0	10100000	011101010	E0	11100000	011101110
A1	10100001	001101010	E1	11100001	001101110
A2	10100010	101010010	E2	11100010	111010010
A3	10100011	101010011	E3	11100011	111010011
A4	10100100	010101010	E4	11100100	010101110
A5	10100101	101010101	E5	11100101	111010101
A6	10100110	101010110	E6	11100110	111010110
A7	10100111	101010111	E7	11100111	111010111
A8	10101000	111101010	E8	11101000	111101110
A9	10101001	101011001	E9	11101001	111011001
AA	10101010	101011010	EA	11101010	111011010
AB	10101011	101011011	EB	11101011	111011011
AC	10101100	110101010	EC	11101100	110101110
AD	10101101	101011101	ED	11101101	111011101
AE	10101110	101011110	EE	11101110	111011110
AF	10101111	101011111	EF	11101111	111011111
B0	10110000	011101011	F0	11110000	011101111
B1	10110001	001101011	F1	11110001	001101111
B2	10110010	101110010	F2	11110010	111110010
B3	10110011	101110011	F3	11110011	111110011
B4	10110100	010101011	F4	11110100	010101111
B5	10110101	101110101	F5	11110101	111110101
B6	10110110	101110110	F6	11110110	111110110
B7	10110111	101110111	F7	11110111	111110111
B8	10111000	111101011	F8	11111000	111101111
B9	10111001	101111001	F9	11111001	111110011
BA	10111010	101111010	FA	11111010	111110101
BB	10111011	101111011	FB	11111011	111110111
BC	10111100	110101011	FC	11111100	110101111
BD	10111101	101111101	FD	11111101	111111011
BE	10111110	101111110	FE	11111110	111111110
BF	10111111	101111111	FF	11111111	111111111
Position in byte	8 1	9 1	Position in byte	8 1	9 1

Appendixes (These Appendixes are not part of American National Standard X3.180-1990, but are included for information only.)

Appendix A Recommendations for Transportation

A1. Environment

It is recommended that during transportation the cartridges are kept within the following conditions:

A1.1 Unrecorded Cartridge. The packaged, unrecorded, tape cartridge should be capable of:

Temperature:	-23°C to +48°C (-9°F to +120°F)
Relative humidity:	5% to 100%
Maximum wet bulb temperature:	26°C (80°F)
Duration:	10 consecutive days

There should be no condensation in or on the cartridge.

A1.2 Recorded Cartridge

Temperature:	5°C to 32°C (40°F to 90°F)
Relative humidity:	5% to 80%
Maximum wet bulb temperature:	26°C (80°F)

There should be no condensation in or on the cartridge.

A2. Hazards

Transportation of tape cartridges involves three basic potential hazards.

A2.1 Impact Loads and Vibrations. The following recommendations should minimize damage to tape cartridges during transportation:

- (1) Avoid mechanical loads that would distort the cartridge shape.
- (2) Avoid dropping the cartridge more than 1 meter (39 inches).
- (3) Cartridges should be fitted into a rigid box containing adequate shock-absorbent material.
- (4) The final box must have a clean interior and a construction that provides sealing to prevent the ingress of dirt and water.
- (5) The orientation of the cartridges inside the final box should be such that their tape-reel axes are horizontal.
- (6) The final box should be clearly marked to indicate its correct orientation.

A2.2 Extremes of Temperature and Humidity. Extreme changes in temperature and humidity should be avoided whenever possible. Whenever a cartridge is received, it should be conditioned in the operating environment for a period of at least 24 hours.

A2.3 Effects of Stray Magnetic Fields. A nominal spacing of not less than 80 mm (3.15 inches) should exist between the cartridge and the outer surface of the shipping container. This should minimize the risk of corruption.

Appendix B

Tape Durability

Testing and measurements performed on the cartridge using appropriate models of IBM tape drives, or equivalent, are described in Sections B1 and B2.

B1. Short-Length Durability and Reliability Test

Short-length durability is the capability of the tape to withstand the wearing action encountered during repeated accesses to a short file of data. A permanent coincident dropout is one that persists for ten consecutive read passes.

B1.1 Requirement. No permanent coincident dropouts are permitted for a minimum of 40 000 read-forward passes. In addition, no more than one permanent coincident dropout is permitted on average for each 80 000 read-forward passes.

B1.2 Procedure. Ensure the tape drive is clean before starting this test.

As a test sample, use a minimum of four cartridges, written in an area free of coincident dropouts. The area to be tested on each cartridge should be approximately 500 25-Kbyte records past the tape-load point. The test area should consist of 50 25-Kbyte records.

Each test cycle consists of a start operation at the beginning of the test area accessing all records sequentially in the test area, and, using the backspace file, returning to the beginning of the test area. For a complete test, 80 000 cycles should be made on each cartridge. Ten attempts to read forward should be made for each coincident dropout before a permanent coincident dropout is logged.

Tape-path cleaning between passes is not permitted for this test.

The test must be performed in a normal operating environment for the tape and the tape drive.

B2. Long-Length Durability and Reliability Test

Long-length durability is the capability of the tape to resist the wearing action encountered while cycling full length on a tape drive.

B2.1 Recommendation. The cartridges should meet the following criteria:

(1) The coincident dropout rate (average per pass) for the first 200 full passes must be no more than 6 per 165 meters (541 feet) of written tape.

(2) There may be no more than 12 coincident dropouts for each 165 meters (541 feet) of tape on any single pass.

B2.2 Procedure. Clean the tape drive before starting this test. The data written should consist of at least 16-Kbyte records.

Tape-path cleaning between passes is not permitted for this test.

The test must be performed in a normal operating environment for the tape and tape unit.

Appendix C

Pre-Record Condition

C1. Explanation

The pre-record condition is the remanent magnetic moment of the recording surface. The remanent magnetic moment is the magnetic moment of the recording surface in the absence of any magnetizing field. The maximum remanent magnetic moment of the recording surface is the remanent magnetic moment of the recording surface after subjecting the recording surface to a magnetizing field of 350 kA/M (4400 Oe). The recording surface may have been subjected to a high magnetizing field, for example, during manufacture, during testing, or by use on a magnetic recording system that leaves areas of surface that have been dc-erased or contain low-density transitions. As the resulting high magnetic moment can impair the operation of the recording system, it is necessary to ensure that, before recording, the remanent state has been reduced to, at most, the level specified in the body of the text.

C2. Procedure

The magnetic moment should be measured using a vibrating sample magnetometer (VSM), following these steps:

- (1) Use a 6-mm to 12-mm (0.24-inch to 0.47-inch) sample disk of tape.
- (2) Identify the longitudinal (coating) direction of the sample.
- (3) Mount the disk on the VSM sample holder with the longitudinal direction aligned from pole to pole.
- (4) Center the disk between the poles in accordance with the VSM manufacturer's instructions.

CAUTION: Do not expose the disk to any stray or ambient magnetic fields during preparation or mounting.

- (5) Measure the remanent magnetic moment of the disk.
- (6) Rotate the disk 180° and repeat steps 4 and 5.
- (7) Cycle the disk four times around the hysteresis loop using a peak field of 350 kA/m (4400 Oe).
- (8) Measure the positive and negative values of maximum remanent magnetic moment.
- (9) Compare the ratio of values obtained in steps 5 and 8.

Appendix D

Measurement of Bit Shift

The equipment normally used for recording interchange cartridges should be used for recording the tape under test.

The tape should be in the pre-record condition as described in 5.14.

The tape should be written in any start-stop mode compatible with system operation.

D1. Read Equipment

The tape should be read on any tape transport in which the speed is within ± 1 percent of nominal speed.

There are no absolute requirements on the output voltage from the read head. However, the head design and the tape speed should be chosen to avoid problems from low signal-to-noise ratios.

(1) Read Head

(a) *Inductive Head*. The gap length should be less than $0.63 \mu\text{m}$ ($24.8 \mu\text{in}$).

(b) *Magneto-Resistive*. The effective read gap, calculated from the geometric mean of the distances from the element to each shield, should be less than $0.63 \mu\text{m}$ ($24.8 \mu\text{in}$).

The azimuth alignment of the read head gap and the mean flux transition line of the written track should be less than 9 minutes of arc.

(2) *Read Channel*. The frequency response of the head and read amplifier should meet the following specification when tested with a wire placed close to and parallel to the read gap.

For an inductive head, the overall response should be within 1 dB from a +6 dB/octave line over the frequency range corresponding to one-twentieth of the ONEs frequency to 2.0 times the ONEs frequency. For example, a tape transport operated at 762 mm/s (30.0 in/s) would require a frequency range of 18.5 kHz to 740.7 kHz. The phase response should be within 2 degrees of a straight line over the same frequency range.

For a magneto-resistive head, the overall response should be within 1 dB of flat over the above frequency range and the phase response should be within 2 degrees of a straight line over the same frequency range.

Response of either read channel should roll off at 18 dB/octave starting at 2.0 times the ONEs frequency.

D2. Measurement

The average bit-cell length (l) is obtained from any pair of reference zero crossings (RZC) located on either side of the test zero crossing (TZC). A reference zero crossing is a ONE zero crossing with at least two adjacent ONE zero crossings on each side. The reference zero crossings should not be more than 40 bit cells apart to keep the maximum error due to rate-of-change under 2 percent.

D3. Data Analysis

Data analysis should be performed in accordance with Figure D1. If N is the number of bit cells between reference zero crossings, the average bit-cell length is:

$$l = (P_3 - P_1) / N$$

If there are M bit intervals between the first reference zero crossing and the test zero crossing, then:

$$\text{percent bit shift} = 100 \times (lM \times l - (P_2 - P_1)) / l$$

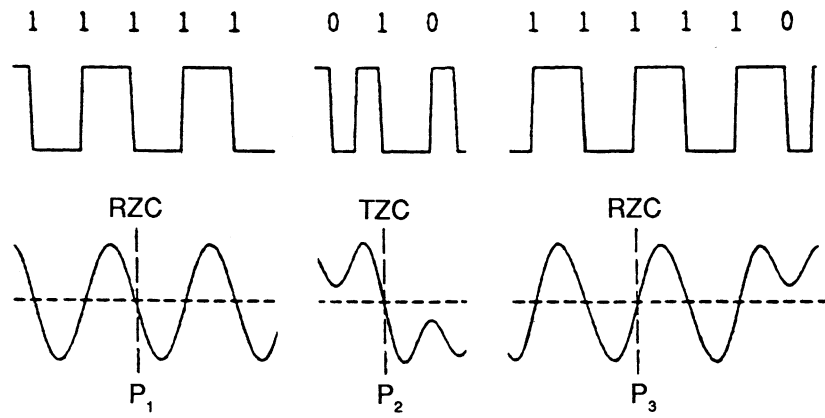


Figure D1
Data Analysis

where: RZC is a reference zero crossing.
TZC is the test zero crossing.
 p_n is the position of the n th ONEs zero crossing.